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MEASUREMENTS OF TWINS

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ARCHIVES OF

PHILOSOPHY, PSYCHOLOGY AND SCIENTIFIC METHODS

EDITED BY

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PREFACE.

This research was made possible by a grant from the ESTHER HERRMAN RESEARCH FUND of the Scientific Alliance of New York and by the courteous assistance of many teachers and principals of schools in New York City. It should be dedicated, if any dedication were permissible, to 'The disinterested love of science and the intelligent cooperation of professional men and women.'

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INTRODUCTION

THIS monograph will present (1) the results of precise measurements of fifty pairs of twins from 9 to 15 years old in six mental traits and (2) their bearing upon the comparative importance of heredity and environment as causes of human differences in intellectual achievement. They will be found to give well-nigh conclusive evidence that the mental likenesses found in the case of twins and the differences found in the case of non-fraternal pairs, when the individuals compared belong to the same age, locality and educational system, are due, to at least nine tenths of their amount, to original nature. They justify the emphasis put upon the magnitude of heredity as a cause of the mental differences amongst men by Galton, Pearson, Woods and others and suggest many practical applications in education and other social arts.

Besides discussing this main theme, I shall note certain evidence concerning the mode of genesis of twins, the specialization of inheritance, and the relation between physical and mental inheritance.

CHAPTER I

Original Nature versus Training as the Cause of the Mental Resemblances of Twins

§ 1. *The General Argument*

The general argument which the reader will follow through a necessary mass of detail is as follows:

We inquire concerning those causes which make one of a twin pair resemble the other. We mean by resemblance any greater likeness than would be found in a pair of children of the same age and sex picked at random from the school population of New York City. We measure it by (A) the smallness of the difference between the measure of one twin and that of the other or by (B) the extent to which the two vary from the central type for their age and sex in the same direction and in equal amount. For instance, suppose that all the boys in the New York school population who are exactly 12 years and 82 days old are found to be distributed with respect to circumference of head around a central type of 53 centimeters, with a median difference between any two such boys, picked by chance, of 4.2 cm.; and suppose that John and James Smith, twins of that age, measure 57.2 cm. and 56.6 cm. Then John and James show close resemblance; for (A) their difference is only one seventh the chance difference and (B) they are respectively $+4.2$ and $+3.6$ from the central type for their age and sex. The second type of measure is for many reasons preferable, and will be used throughout. Measures of the general tendency to resemblance in the group of 50 twin pairs are thus obtained in the case of each mental measurement taken. These measures of resemblance will be presented in the form of Pearson coefficients of correlation corrected for attenuation by the methods described by Spearman.[1]

If now these resemblances are due to the fact that the two members of any twin pair are treated alike at home, have the same parental models, attend the same school and are subject in general to closely similar environmental conditions, then (1) twins should, up to the age of leaving home, grow more and more alike, and in our measurements the twins 13 and 14 years old should be much more alike than those 9 and 10 years old. Again (2) if similarity in training is the cause of similarity in mental traits, ordinary

[1] *American Journal of Psychology*, January, 1904.

fraternal pairs not over four or five years apart in age should show a resemblance somewhat nearly as great as twin pairs, for the home and school condition of a pair of the former will not be much less similar than those of a pair of the latter. Again, (3) if training is the cause, twins should show greater resemblance in the case of traits much subject to training, such as ability in addition or in multiplication, than in traits less subject to training, such as quickness in marking off the A's on a sheet of printed capitals, or in writing the opposites of words.

On the other hand, (1) the nearer the resemblance of young twins comes to equaling that of old, (2) the greater the superiority of twin resemblance to ordinary fraternal resemblance is, and (3) the nearer twin resemblance in relatively untrained capacities comes to equaling that in capacities at which the home and school direct their attention, the more must the resemblances found be attributed to inborn traits.

The argument is thus straightforward enough once we get absolutely exact and reliable measures of resemblance. Using convenient symbols, it is as follows:

Let $r_{t.}$ = the resemblance of twins.
Let $r_{s.}$ = the resemblance of siblings.
Let $r_{9\text{-}11}$ = the resemblance of twins 9 yrs. 0 months to 12 yrs. 0 months old.
Let $r_{12\text{-}14}$ = the resemblance of twins 12 yrs. 0 months to 15 yrs. 0 months old.
Let $r_{t.\ in\ untr.}$ = the resemblance of twins in traits little subject to home training.
Let $r_{t.\ in\ tr.}$ = the resemblance of twins in traits much subject to home training.

Then the influence of original nature in determining resemblances is in proportion to the extent that

$$r_{t.} > r_{s.}$$
$$r_{9\text{-}11} = r_{12\text{-}14}$$
$$r_{t.\ in\ untr.} = r_{t.\ in\ tr.}$$

Conversely, the influence of the environment in determining resemblance is in proportion to the extent that

$$r_{s.} = r_{t.}$$
$$r_{9\text{-}11} < r_{12\text{-}14}$$
$$r_{t.\ in\ untr.} < r_{t.\ in\ tr.}$$

If absolutely accurate measures of the resemblances considered were at hand, this argument could be followed clearly and its meaning estimated in a very brief time.

Such absolute accuracy is of course not obtained in my measures. To make clear the probable influence of the various factors which may make my obtained measures of resemblance vary from the true measures which would result from complete information about an infinite number of twins, I must describe at some little length the method of getting measurements and computing resemblances. This

will be done later in Chapter II. For the present it will suffice to bear in mind the summary given in the next section.

§ 2. *The Possible Causes of Variable and Constant Errors*

These are:

1. The number of pairs of twins measured.
2. The number of mental traits measured in each individual.
3. The number of measurements taken of each trait in each individual.
4. The number of individuals from whose measurements the central tendencies for each age and sex are obtained.
5. The number of individuals from whose measurements the comparative variabilities for each age and sex are obtained.
6. The uncertain equality of the units of measure treated as equal in the calculation of each individual's ability in each trait.
7. The possibly unfair selection of twins for measurement.
8. The fact that the two members of any pair of twins were commonly tested together.

Factors 1–5 can be measured and their influence calculated. A full account of them will be found in Chapter II., § 12.

Factors 6–8 can only be estimated inexactly from certain general evidence. A full account of them will be found in Chapter II., § 12.

I may say here only that the number of cases (50 pairs) would be sufficient to give a high degree of probability to every general conclusion drawn from the measurements, if it alone were concerned; that the number of traits taken is not sufficient to measure exactly the general mental similarity of twins, and that when I use the term mental similarity or resemblance or the like I shall mean not similarity *in toto*, but only similarity in the group of traits here measured, viz.:

a. Efficiency in finding and marking A's distributed amongst other capital letters.

b. Efficiency in finding and marking words each to contain two certain letters (*e. g.*, *e* and *r*) distributed amongst other words in a jumble (Spanish words being used).

c. Efficiency in finding and marking misspelled words in a page of easy English containing some 100 misspellings.

d. Efficiency in addition.

e. Efficiency in multiplication.

f. Efficiency in writing words meaning each the opposite of one of a set of given words.

The effect of factor 3 is to make estimates of the average resemblance of a series of pairs somewhat more unreliable than would appear from the mere smallness of the number of pairs, *and much*

too low. The greater the inaccuracy in the individual measures, the more will the true resemblance exceed that obtained. We can correct for this 'attenuation' of the resemblance, provided we have at least two independent measures of the trait in question in each individual of a reasonably large group. For the methods of so doing, see C. Spearman's article in the *American Journal of Psychology,* January, 1904. Except in the misspelled word test, my data permit this correction, though with a possibility of slight constant error. I take Mr. Spearman's method of correction for attenuation on trust, as I do not possess the mathematical knowledge necessary to derive his formulæ.

The effect of factor 4 is to make estimates of the average resemblance of a series of pairs somewhat more unreliable than would appear from the mere smallness of the number of pairs, and in so far as the central tendencies are calculated to fit the twins themselves, to make the average resemblance obtained very slightly lower than the true resemblance. This is approximately the case in the present research. The attenuation so caused is, however, negligible.

The effect of factor 5 is to make the obtained values of the average resemblance of a series of twin pairs too low, in so far as the twins are of different sex (it is like that of factor 3, chance inaccuracies in the original measure); and to make the twins of the ages that are the more variable count unduly in determining the resembance.

The effect of factor 6 is complicated. It would act partly as a source of chance inaccuracy in the original measures and partly as an influence unduly weighting certain pairs. In §'12 I shall give evidence to show that it is of small consequence.

All the factors so far mentioned are of minor importance for our general argument, since their action is either of very small amount, or can be corrected for, or is as likely to raise as to lower the estimate of resemblance. The case is different with factors 7 and 8. If the 50 pairs of twins chosen for measurement represented extreme cases of resemblance, the obtained resemblance would be much higher than the resemblance of twins in general and all conclusions from a comparison of them with ordinary fraternal pairs would be subject to a serious constant error. If the conditions of testing for one pair of twins were very similar and much unlike the conditions for another pair, the resemblance obtained would again be too high, being due to similarity of conditions of testing rather than to similarity of original nature.

The method of discovering twins was as follows: Teachers in certain schools were asked to inquire of their classes whether any one had a brother or sister of the same age

reported were tested. But also frequently some teachers would report that in such and such a school there was a pair of twins. These could then be found quickly and measured. These reported cases were perhaps likely to have been noticed in the first case because of their likeness and so to be an unfair selection. Again, in the New York schools it is usual to separate the sexes after three or four years of school life and it is a frequent practice to separate them from the start. Twins of like sex are therefore more conveniently obtained and so more often tested than their general frequency would recommend. The amount of the resulting constant error is not, however, great,[1] as I shall show in § 12.

The tests were all made by the same individual and in the same way except for unconscious changes. However, in respect to time of day, conditions of weather and light, and in such conditions as are determined by family life, *e. g.*, the lack of breakfast, fatigue from a party the previous night and the like, two twins would, when measured at the same time, be influenced alike. Thus the obtained resemblance would be too large. I can evaluate the amount of the resulting constant error only from general considerations. I believe it to be small. This constant error would also influence the correction made for attenuation, but here would make the obtained resemblance too small.

On the whole it is likely that the reader who has made similar measurements of school children and who will read Chapter II. with care, will agree with me that the probable increase of the obtained over the true relationship due to those two sources of constant error is at least roughly balanced by the probable decrease of the obtained below the true relationship due to factors 4 and 5 and to the allowance to be made in using Spearman's method of correction, because of factor 5. It should also be noted that with respect to our general argument concerning the influence of training *versus* that of original nature, the influence of all these sources of error is immaterial. If my figures for twins' resemblance were proved to be even .20 too high, there would result only a weakening of the argument from the comparison of twins with ordinary siblings.

I have every reason to try to make the estimates free from any serious constant error and, if any complicated system of corrections could help, would gladly make them. But, so far as I can judge, the results obtained directly are probably nearer the truth than any speculative alterations of them would be.

As to the mere chance variations of the obtained from the true

[1] Of the 50 pairs of twins measured there are apparently only 3 more of the would be expected from a random selection.

measures of resemblance, I have estimated them only roughly from a consideration of all the chances, to evaluate which exactly would take a year of numerical labor. My estimates are too large rather than otherwise, I fancy. The basis for them is given in § 12.

The reader who prefers to accept my judgment rather than his own may then follow the argument through the next sections in the data of tables 1–3, which compare the resemblances of twins with those of ordinary fraternal pairs, the resemblances of young with those of old twins, and the resemblance in the traits little subject to training with the resemblance in traits much subject to training.

The reader who wishes to judge critically or to study the methods of the investigation will find at least the majority of his questions answered in Chapter II.

§ 3. *The Resemblances of Twins and of Siblings*

From the information at hand, which is not so satisfactory as information I hope to obtain during the next few years, the resemblance of twins in mental traits is roughly twice that of ordinary siblings;[1] according to the actual figures of my measurements of siblings, more than twice. I have reason, however, to believe that the correlation coefficients obtained for siblings are affected by constant errors which make them too low; namely, the selection of mentally unlike pairs by the conditions of the methods of obtaining siblings and the absence of suitable data to make sufficient correction for attenuation. Table 1 gives the facts.

In this and following sections I shall use the words *'resemblance of'* and *'likeness of'* as synonyms for *'coefficient of correlation between.'* A resemblance of .50 means then a Pearson correlation coefficient of .50. I shall use the terms A test, word test, misspelled word test, opposites test, addition and multiplication to mean the tests, or at times the abilities measured by the tests, mentioned in § 2 and described fully in § 8.

TABLE 1

The resemblances of twins and siblings compared

Ability	Coefficients of Correlation	
	Twins	Siblings
A test	.69	.32
Word test	.71	.29
Opposites test	.90	.30

For descriptions of the tests see § 8. I give for siblings the obtained results. Since the correction for attenuation had to be made in an imperfect form the true resemblances are probably somewhat higher, but not over .40.

[1] Karl Pearson has pointed out that the w
to denote children of the same parents.

§ 4. *The Resemblances of Young and of Old Twins*

The older twins show no closer resemblance than the younger twins, and the chances are surely four to one that with an infinite number of twins tested the 12–14 year olds would not show a resemblance .15 greater than the 9–11 year olds. The facts are given in Table 2.

TABLE 2

The resemblances of young and old twins compared

	In Corrected Coefficients		In Raw Coefficients	
	Twins 9–11	Twins 12–14	Twins 9–11	Twins 12–14
1) A test	66	73	58	67
2) Word test	81	62	62	49
3) Misspelled word test	76	74	76	74
4) Addition	90	54	83	46
5) Multiplication	91	69	81	53
6) Opposites	96	88	79	78
Marks in 1), 2) and 3) combined			71	69
Marks in 4), 5) and 6) combined			90	75
Averages	83	70	75	64

§ 5. *The Resemblances in Traits Little and in Traits Much Subject to Training*

The variations in the closeness of resemblance of the twins in the different traits show little, and possibly no, direct correlation with the amount of opportunity for environmental influences. The traits most subject to training (addition and multiplication) do show closer resemblances than the traits least subject to training (the A test and word test); but on the other hand show less close resemblances than the traits moderately subject to training (the misspelled word test and opposites test). The hypothesis that the true resemblance varies in amount *inversely* with the amount of opportunity for environmental influence would not be irreconcilable with the facts, and the hypothesis that the differences between the different traits are due to chance (including in that term the variable errors of the measurements and the possibility of the unequal inheritance of different traits) is the most probable of all. The difference between the traits most subject and those least subject to training is no greater than the median difference between any one trait of the six and any other. Surely there is no evidence here of any large contribution from similarity of training to similarity of achievement. The facts are given in Table 3.

TABLE 3

The resemblances of twins in traits little and in traits much subject to training

	Coefficients of Correlation	Averages
1) A test	.69	.70
2) Word test	.71	
3) Misspelled word test	.80 (?)[1]	.85 +
6) Opposites test	.90	
4) Addition	.75	.795
5) Multiplication	.84	
Marks in 1), 2) and 3) combined	.70 (raw)[2]	
Marks in 4), 5) and 6) combined	.82 (raw)[3]	

§ 6. *The Resemblances in Mental Traits Compared with the Resemblances in Physical Traits*

It is highly probable from the facts given in §§ 3–5 that the similarity of twins in ancestry and conditions of conception and birth accounts for almost all of their similarity in mental achievement,—that only a small fraction of it can be attributed to similarity in training. On general principles it is also highly probable that similarity of ancestry and conditions of conception will produce equal similarity in original physical nature and in original mental nature. Certain resemblances in original physical nature are in all probability neither increased nor decreased by such similarities and differences of home training as act upon twins and non-related children, respectively, within a group such as ours; *e. g.*, resemblances in cephalic index, ratio of height sitting to total height, eye color and hair color. Other resemblances in original physical nature are so increased and decreased slightly and perhaps not at all; *e. g.*, circumference of head, length of head, width of head, length of forearm and length of finger joints.

If then the resemblances of twins were almost entirely due to original nature, we should expect them to be only slightly in excess of the resemblances in physical traits. The existence of the latter as a fact may properly be taken as a partial verification of the former as a general hypothesis. The evidence of its existence is given in Table 4.

§ 7. *Summary and Criticism*

The facts of §§ 3–6 prove that among one hundred twins living and attending school in New York City in 1903–4, the mental resemblances of a twin pair are about twice as great as those of a pair

[1] The raw coefficient was .754. I have no means of correcting for attenuation except indirectly. The corrected coefficient would be at least .80.

[2] The correction for attenuation would increase this only slightly, since it is derived from seven trials. The true r can hardly be above .75.

[3] The case is as noted in 2. The true r can har

TABLE 4

The resemblances of twins in mental and in physical traits

In Mental Traits		In Physical Traits	
1. A test	.69	11. Cephalic index	.76
2. Word test	.71	12. Ht. sitting/ht.	.76
3. Misspelled	.80 +	13. Height	.78
4. Addition	.75	14. Height sitting	.83
5. Multiplication	.84	15. Circ. of head	.75
6. Opposites	.90	16. Width of head	.86
7. Combined mark in 1–3	.70 +	17. Arm length	.72
8. Combined mark in 4–6	.82 +	18. Finger length	.71

7, 8 and 12–15 are raw correlations and the correction for attenuation might raise them by .01 or .02.

Median of 1-6	.78	Average of 11-12	.76 (possibly .77)
		" 13-18	.77 (possibly .78 or .79)
Average of 1-6	.78	Median of 13-18	.77 (possibly .78 or .79)
		" 11-18	.76 (possibly .77)
Average of 7-8	.76 (possibly .80)	Average of 11-18	.76 (possibly .77)

of siblings similarly chosen, are as great or nearly as great in the case of the younger as of the older half of the group, are as great or nearly as great in the case of the A, word, misspelled word and opposites tests as in the case of addition and multiplication, and are only slightly, if at all, greater than resemblances in physical traits which could have been caused, in some cases, only by original nature.

The facts are easily, simply and completely explained by one simple hypothesis: namely, that the natures of the germ cells—the conditions of conception—cause whatever similarities and differences exist in the original natures of men, that these conditions influence body and mind equally, and that in life the differences in modification of body and mind produced by such differences as obtain between the environments of present-day New York City public school children are slight.

Certain other hypotheses seem possible at first sight, but become involved in great difficulties when one tries to explain all the facts by any of them. These difficulties I will point out briefly.

It may be said that all that has been proved of the twins is that they are alike in general mental maturity (*i. e.*, in the points of development which they have reached).

Traits like those tested are of course influenced by maturity directly and indirectly through the relation between maturity and advance in school and the relation between the latter and certain of the traits tested. But maturity is by no means the total cause of efficiency in these traits. Nor is it a cause comparable in amount of influence with individual differences apart from maturity. Nor is there any evidence that there is any greater resemblance of twins in maturity than in other factors, such as eyesight. If maturity

were the total cause of efficiency in the six traits measured, these traits should in the same individual show perfect correlation with each other. They do not, nor, indeed, enough correlation to assign maturity a very important place as a contributory cause. If resemblance in maturity were the cause of the resemblances found, these should be largest in the traits most subject to maturity. The opposite is the case.

It may be said that all that has been proved of the twins is that the environmental conditions from 9 to 14 years count little; that the similarities in environment *in utero* and during childhood are left as possible causes of the resemblances found; and that these are the real causes. But that the conditions *in utero* are the cause of the resemblances of related individuals is disproved by the fact that paternal is as great as maternal resemblance in the case of those traits where parents and offspring have been compared; and that similarities in environment from 0 to 9 years should produce a far greater effect on the children's abilities to add, multiply, mark misspelled words and write opposites than do similarities in environment from 9 to 15 is a notion utterly devoid of probability.

It is equally difficult to accept original nature as a cause of a moderate amount of the resemblance found and to explain the rest as due to training. Suppose, for instance, that some one assumes that the force of the germ-natures,—of the conditions of conception,—is sufficient to produce a resemblance of .20 in siblings and .40 in twins in mental traits. He must then be willing to believe that the likeness in training of a twin pair is enough greater than the likeness in training of a sibling pair, two or three years apart in age, to make the .40 rise to .80, whereas the .20 rises only to .40 or less. He must also be willing to believe either that inborn mental make-up is inherited by a totally different law from that regulating inborn physical make-up or else that the similarities in training of twins will raise .40 to .80 in physical traits such as cephalic index, and that the similarities in training of siblings will raise the .20 only to .40 or .50. He must also place the bulk of influence of this training previous to the tenth year and assume that it is of such a generalized sort as would raise the resemblances in marking A's or words containing *r* and *e* as much as that in multiplication.

Doubtless we all feel a repugnance to assigning so little efficacy to environmental forces as the facts of this study seem to demand; but common opinion also feels a repugnance to believing that the mental resemblances of twins, however caused, are as great as the physical resemblances. Yet they are. I can not here discuss the general facts and detailed studies which bear upon the question of the amount of influence of such likenesses and differences in environment as existed in the case of these twins.

I shall also spend but little time in comments upon the application of the facts so far presented to theories of education and human action and to the practical problems of social control. The inferences with respect to the enormous importance of original nature in determining the behavior and achievements of any man in comparison with his fellows of the same period of civilization and conditions of life are obvious. All theories of human life must accept as a first principle the fact that human beings at birth differ enormously in mental capacities and that these differences are largely due to similar differences in their ancestry. All attempts to change human nature must accept as their most important condition the limits set by original nature to each individual.

We must be careful, however, not to confuse two totally different things: (1) the power of the environment,—for instance, of schools, laws, books and social ideals,—to produce differences in the relative achievements of men, and (2) the power of the environment to produce differences in absolute achievement. It has been shown that the relative differences in certain mental traits which were found in these one hundred children are due almost entirely to differences in ancestry, not in training; but this does not in the least deny that better methods of training might improve all their achievements fifty per cent. or that the absence of training, say in spelling and arithmetic, might decrease the corresponding achievements to zero. Similarly, the fact that Mr. Rockefeller has amassed one of the great fortunes of the age is undoubtedly due almost exclusively to his original capacity, not to circumstances; but this does not deny that it is almost exclusively circumstances which make the average wealth of men to-day greater than it was a thousand years ago or that future changes in the environment might, without any change in capacity, make nine men out of ten the owners of automobiles, race-horses, tall hats and the other blessings of wealth.

The argument has been limited entirely to the causes which make one person differ from another in mental achievements *under the same general conditions of life at the beginning of the twentieth century in New York City as pupils in its school system.* If the resemblance of twins had been measured in the case of a group made up partly of New York City school children and partly of children of equal capacity brought up in the wilds of Africa, the variability of the group in addition and multiplication would have increased and the correlation coefficients would rise. They would then measure the influence of original nature plus the now much increased influence of the environment.

The relative impotence of such similarities of home training as existed in our fifty pairs of twins to create similarities of achievement does, however, make one suspect that the magnitude of the

influence of the training given by schools, periods of civilization and the like has been exaggerated. For other reasons, also, I imagine this to be the case, but to prove or disprove it, one would need data quite different from the records of these hundred twins.

It is then folly to conclude that the inheritance of mental capacities from immediate ancestry implies the futility of education and social control in general,—the wisdom of fatalism and *laissez faire*. Such studies as this merely prove the existence of and measure one determinant of human intellect and character and demonstrate that the influences of the environment are differential, the product varying not only in accord with the environmental force itself but also in accord with the original nature upon which it operates. We may even expect that education will be doubly effective, once society recognizes the advantages given to some and denied to others by heredity. That men have different amounts of capacity does not imply any the less advantage from or need of wise investment. If it be true, for example, that the negro is by nature unintellectual and joyous, this does not imply that he may not be made more intelligent by wiser training or misanthropic and ugly-tempered by the treatment he now receives. It does mean that we should be stupid to expect the same results from him that we should from an especially intellectual race like the Jews, and that he will stand with equanimity a degree of disdain which a Celt would requite with dynamite and arson.

To the real work of man for man,—the increase of achievement through the improvement of the environment,—the influence of heredity offers no barrier. But to the popular demands from education and social reforms it does. For the common man does not much appreciate absolute happiness or absolute betterment. He does not rejoice that he and his children are healthier, happier and more supplied with noble pleasures than were his ancestors of a thousand years ago. His complaint is that he is not so well off as some of those about him; his pride is that he is above the common herd. The common man demands *relative* superiority,—to be above those of his own time and locality. If his son leads the community, he does not mind his real stupidity; to be the handsomest girl in the county is beauty enough. Social discontent comes from the knowledge or fancy that one is below others in welfare. The effort of children in school, of men in labor and of women in the home is, except as guided by the wise instincts of nature or more rarely by the wisdom of abstract thought, to rise above some one who seems higher. Thus the prizes which most men really seek are after all in large measure given or withheld by [illegible]al nature. In the actual race of life, which is not to ge[illegible] of somebody, the chief determining facto[illegible]

CHAPTER II

The Measurements of Mental Resemblance: Data and Methods

§ 8. *The Original Measures*

Fifty pairs of twins from 9 years 0 months to 14 years 11 months old were measured. Thirty more pairs under 9 and over 15 were also tested but are not considered in this paper, as I have not at present data sufficient to calculate the central tendencies for children outside of the 9–15 year limits and so can not estimate accurately the resemblance of the younger and older pairs. The children were located with the help of many courteous and efficient school principals in New York and were all measured by the same person, Miss J. R. Seibert, assistant in the department of Educational Psychology of Teachers College. The tests given were as follows:—

1 A. To mark in a minute as many A's as possible on a blank (Fig. 1 A) containing capital letters mixed. This test was given twice.

1 B. To mark in a minute as many A's as possible on a blank (Fig. 1 B) containing capital letters mixed. This test was also given twice.

2 A. To mark in two minutes as many words as possible containing both *a* and *t* on a blank (Fig. 2) containing Spanish words.

2 B. To mark in two minutes as many words as possible containing both *e* and *r* on a blank (Fig. 2) containing Spanish words.

3. To mark in three minutes as many misspelled words as possible on a blank (Fig. 3) containing many misspelled words.

4. To add as rapidly and with as few mistakes as possible for two minutes. The examples used are shown in Fig. 4. This test was given twice.

5 A. To multiply as rapidly and as well as possible for four minutes. The examples used are shown in Fig. 5 A.

5 B. To multiply as rapidly and as well as possible for four minutes. The examples used are shown in Fig. 5 B.

6 A. To write in a minute as many words as possible, each meaning the opposite of a given word. The children were told to write 'beside each word the word which means just what the word you see doesn't mean' and were given preliminary practise with good—work—play, day—night. The given words were those in the

6 A. They were printed in a column on a blank.

in a minute as many words as possible each mean-

ing the opposite of a given word. The children were told to write 'beside each word the word which means just what the word you see doesn't mean' and were given preliminary practise with good—bad, work—play, day—night. The given words were those in the column under 6 B.

The tests were all scored by the same methods and, in the case of the addition, multiplication and opposites tests, all by the same person. The scores given were as follows:—

1. A test. The number of A's marked in each of the four trials.

2 A. *a-t* test. The number of words containing *a* and *t* marked and the number of words wrongly marked.

2 B. *e-r* test. The number of words containing *e* and *r* marked and the number of words wrongly marked.

3. Misspelled word test. The number of misspelled words marked and the number of words wrongly marked.

4. Addition. The number of half examples done and the number of half examples done with no error, in each of the two trials.

5. Multiplication.—The number of sixths of an example done and the number of sixths of an example done with no error (each partial product was arbitrarily counted as one sixth and the addition of the four as two sixths).

6. Opposites test. The number of correct opposites written, the number of incorrect opposites written, and the number of words skipped in the columns. Half credits were given for certain opposites.

SET No. 1

OYKFIUDBHTAGDAACDIXAMRPAGQZTAACVAOWLYX
WABBTHJJANEEFAAMEAACBSVSKALLPHANRNPKAZF
YRQAQEAXJUDFOIMWZSAUCGVAOABMAYDYAAZJDAL
JACINEVBGAOFHARPVEJCTQZAPJLEIQWNAHRBUIAS
SNZMWAAAWHACAXHXQAXTDPUTYGSKGRKVLGKIM
FUOFAAKYFGTMBLYZIJAAVAUAACXDTVDACJSIUFMO
TXWAMQEAKHAOPXZWCAIRBRZNSOQAQLMDGUSGB
AKNAAPLPAAAHYOAEKLNVFARJAEHNPWIBAYAQRK
UPDSHAAQGGHTAMZAQGMTPNURQNXIJEOWYCREJD
UOLJCCAKSZAUAFERFAWAFZAWXBAAAVHAMBATAD
KVSTVNAPLILAOXYSJUOVYIVPAAPSDNLKRQAAOJLE
GAAQYEMPAZNTIBXGAIMRUSAWZAZWXAMXBDXAJZ
ECNABAHGDVSVFTCLAYKUKCWAFRWHTQYAFAAAOH

FIG. 1 A

SET No. 2

GAAQYEMPAZNTIBXGAIMRUSAWZAZWXAMXBDXAJZ
ECNABAHGDVSVFTCLAYKUKCWAFRWHTQYAFAAAOH
UOLJCCAKSZAUAFERFAWAFZAWXBAAAVHAMBATAD
KVSTVNAPLILAOXYSJUOVYIVPAAPSDNLKRQAAOJLE
AKNAAPLPAAAHYOAEKLNVFARJAEHNPWIBAYAQRK
UPDSHAAQGGHTAMZAQGMTPNURQNXIJEOWYCREJD
TXWAMQEAKHAOPXZWCAIRBRZNSOQAQLMDGUSGB
FUOFAAKYFGTMBLYZIJAAVAUAACXDTVDACJSIUFMO
SNZMWAAAWHACAXHXQAXTDPUTYGSKGRKVLGKIM
JACINEVBGAOFHARPVEJCTQZAPJLEIQWNAHRBUIAS
YRQAQEAXJUDFOIMWZSAUCGVAOABMAYDYAAZJDAL
OYKFIUDBHTAGDAACDIXAMRPAGQZTAACVAOWLYX
WABBTHJJANEEFAAMEAACBSVSKALLPHANRNPKAZF

FIG. 1 B

A.

Dire tengo antipatia senores; esto seria necedad, porque hombre vale siempre tanto como otro hombre. Todas clases hombres merito; resumidas cuentas, sulpa suya vizxonde; pero dire sobrina puede contar dote viente cinco duros menos tengo apartado; pardiez tamado trabajo atesorar-los para enriquecer estrano. Vizconde rico. Mios, quiero ganado sudor frente salga familia; suyo, pertenence, tendran. Conozco marido pueda convenirle Isabel; Carlos, sobrino. Donde muchacho honrado, mejor indole, juicioso, valiente? Quieres sobrino. Esposo perece natural, pero. Pero, pero, diablos, objeciones hacer. Posible quedandonow solos siempre hacer oposicion. Solo delante hentes eres ministerial. Peus, sidens siempre plan, dicho antes, porque hace tiempo notade cose aflige cierto. Sabes cuante quiero Carlos; consuelo apoyo; despues persona quiero mundo. Como eres buene amable, quieres porque. darme, gusto, pero quisiera. Palabra cuesta trabajo; parece sino teines miedo agasajarle, manifestarle carino. Veces tratas cumplimiento veces senor. Probare; ejemplo pudiendo abandonar case negocios, deseaba hubiese acompanado viaje; preferiste sola sobrina doncella. Quise contradecir, pero para sentimento, para tambien. Voto gasta palabra, dice frases, dice; pero alla adentros quiere. Mientras estado malo, puesto dirigir casa; pardiez aunque carrera, hacia mejor; cabo tiene sobre ventaja poca edad, activadad zelo, pues para contigo digo. Siempre ordenes; dejaria matar alcanzarte billete para opera para baile. Necsitamos para felices; algo estrano, desconocido. Esta resuelto; supuesto hemos hablado esto, mismo, preciso empieces darle conocer nuestros planes. Quien mejor. Opone nunca deseos, sera facil nadie persuadirle. Probare menos, preciso sino creere tienes interes decidido proteger vizconde. Pudieras creer siempre inclinado senores cabra tira monte. Pero tengo nada ellos esposo tienes siempre pensativo siempre trists. Diablos tiene Carlos acercate tiene hablarte. Holo parece sacado letargo tengo algunas instrucciones cajero marcha dentro poco. Para empresa piensa usted establecer Habana. Precisamente bonita especulacion bien manejada sobre todo. Espero poro tengo entre manos ero proyecto interesa aqui estabamos ocupando pienso. Eres porque

FIG. 2

MARK EVERY WORD THAT IS NOT SPELLED CORRECTLY

1. On the 3d of September, 1832, inteligence was broght to the collecter of Tinnevelly that som wildd eliphants had appeared in the neighborhod. A hunting party was imediately formed, and a large number of nattive hunters were engaged. We left the tents, on horsback, at half-past sevin o'clock in the morrning and rode thre miles to an open spote, flanked on one sid bye Rice-fields, and on the other by a jungle.

2. After waiting som time, Captain B——— and myself walked acros the rice fields to the shad of a tree. There we herd the trumpett of an elephant; we reshed acros the rice-fields up to our knes in mud, but all in vaiu, thogh we came upon the trak of one of the animels, and then ran five or six hundredd yards iutoo the jungle.

3. After varius false allarms, aud vane endevors to discuvor the obgects of our chace, the colector went into the jungle, and Captain B——— and myself into bed of the stream' where we had sen the traks; and here it was evedent the elaphents had passed to and fro. Disapointed and impasient, we allmost determened to giv up the chace and go home; but shots fird just before us reanimated us, aud we proceded, and found the collecter had just firred twicce.

4. Of we went throuh forest, over ravin, and through strems, till att last, at the top of the ravine, the elephants were seen. This was a momant of excitment! We wer all scatered. The collector had taken the midle path; Captain B———, some huntsmen, and myself took to the feft; and the other hunters scrabled down that to the rite. At this momunt I did not see enything but after advanceing a few yards, the hugh hed ef an elephunt shaking abuve the jungle, withen ten yards of us, burst sudenly upon my view.

5. Captain B——— ande a hunter justt befor me; we al fired at the same moment, and in so dirrect a line that the percussion-cap of my gun hitt the hunter, whome I thougt at first I had shoot. This acident, thogh it prouved slight, troubled me a litle. The grate excitement ocasioned by seeing, for the first tim, a wild best at liberty and in a state of natur, product a sensation of hop and fear that was intens.

FIG. 3

ADDITION EXAMPLES

17	26	27	72	23
42	51	24	14	47
38	47	83	39	86
91	82	19	81	54
54	63	45	26	36
—	—	—	—	—
17	42	38	91	36
26	51	47	82	26
27	24	83	19	45
72	14	39	62	63
23	47	86	54	54
—	—	—	—	—
41	53	67	78	86
52	67	86	37	32
86	34	23	96	44
23	78	45	72	36
35	19	67	23	68
—	—	—	—	—
45	52	19	45	23
13	86	78	67	72
68	23	67	78	36
77	35	23	37	68
86	67	86	96	39
—	—	—	—	—

FIG. 4

MULTIPLICATION EXAMPLES (1)

7986	7869	9867
4523	5324	3425
8679	7968	7698
3542	3254	5423
8967	7896	6493
4532	5243	8786

FIG. 5 A

MULTIPLICATION EXAMPLES (2)

9468	5426	3795
3752	9378	2684
4932	8376	7264
5764	4925	8539
2869	6492	9425
7453	5763	6387

FIG. 5 B

A	B
good	bad
outside	inside
quick	slow
tall	short
big	little
loud	soft
white	black
light	dark
happy	sad
false	true
like	dislike
rich	poor
sick	well
glad	sorry
thin	thick
empty	full
war	peace
many	few
above	below
friend	enemy

FIG. 6

Occasionally in the *a-t* and *e-r* test, and once in the A test and misspelled word test and multiplication, no exact score could be given because the test was misunderstood. In the multiplication no score could be given to children who had not yet studied multiplication and so could do nothing with it at all. Occasionally also one or more tests of the set had to be omitted.

As a result I have from the 50 pairs:—

47 comparisons in the A test.

44 comparisons in the word test (*a-t* test and *e-r* test).

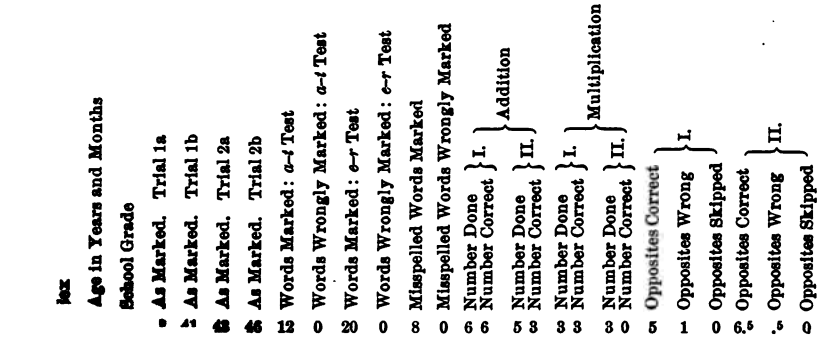
49 comparisons in the misspelled word test.

50 comparisons in addition.

38 comparisons in multiplication.

49 comparisons in the opposites test.

Apart from the omissions thus necessitated we have for each individual a record like the following:



Such records will be termed the gross complex scores. For the sake of any one who may wish to use these in any way, I print them in full (Table 5).

TABLE 5

Gross complex scores

Pair	Individual	Sex	Month Age	Grade	Number of Words Containing *a* and *t* Marked:	Number of Words Containing *e* and *r* Marked	Number of Misspelled Words Marked	Addition: Number Done (1st Trial)	Addition: Number Correct (1st Trial)	Addition: Number Done (2d Trial)	Addition: Number Correct (2d Trial)	Multiplication: Number Done (1st Trial)	Multiplication: Number Correct (1st Trial)	Multiplication: Number Done (2d Trial)	Multiplication: Number Correct (2d Trial)	A's Marked: Trial 1a	A's Marked: Trial 1b	A's Marked: Trial 2a	A's Marked: Trial 2b	Opposites Correctly Written (Trial 1)	Opposites Wrongly Written (Trial 1)	Opposites Correctly Written (Trial 2)	Opposites Wrongly Written (Trial 2)	Words Wrongly Marked: *a-t* Test	Words Wrongly Marked: *e-r* Test	Words Wrongly Marked: Misspelled Test	Words Skipped: Opposites Test 1	Words Skipped: Opposites Test 2
				9 year olds.																								
1	a	b	1	3a	12	20	8	6	6	5	8	3	3	8	0	42	41	43	46	5	1	6.5	.5					
	b	b		3a	15	24	10	7	2	8	4	6	5	6	5	44	48	52	50	6	0	3	0					
2	a	g	2	5a	11	27	51	22	14	24	15	17	11	19	13	39	47	49	50	10	3	10.5	2.5	1	2	4	1	
	b	g		5a	3	11	37	20	18	21	19	13	9	19	9	33	37	47	41	10.5	.5	9	2			1	1	
3	a	g	3	3b	10	21	6	11	10	11	9	0	0	0	0	31	36	39	44	6.5	.5	6	0					
	b	g		3b	10	22	9	9	5	10	8	0	0	0	0	38	40	48	49	6	1	8	0				1	
4	a	g	2	3b	8	10	4	10	9	9	7	0	0	0	0	misunderstood				4.5	1.5	3	1				3	1
	b	b		5a	8	16	11	10	10	9	9	4	4	8	7	25	33	40	29	7.5	.5	4.5	1.5					
5	a	b	1	3b	12	20	8	6	4	5	5	0	0	0	0	21	29	30	32	3.5	.5	3	0					
	b	b		3b	9	18	10	16	14	12	10	0	0	0	0	26	32	33	39	6.5	.5	3	0			1		
6	a	g	5	3b	11	13	14	9	7	12	9	0	0	0	0	38	43	41	40	mis.						1		
	b	g		3b	17	26	14	7	6	7	0	0	0	0	0	30	45	46	39	3.5	1.5	8	0		1	1	1	1
7	a	b	5	2b	8	12	2	10	3	10	7	0	0	0	0	30	27	34	27	4	1	4	1			2		
	b	g		3b	8	15	10	10	10	7	6	0	0	0	0	22	25	31	28	8	0	6	0					
8	a	b	?	4a	13	15	22	10	9	8	7	10	8	7	7	12	25	30	26	5.5	.5	5	0				1	
	b	b		4a	10	23	25	9	8	10	9	7	6	11	9	31	36	30	30	4	1	6.5	0		1	4		
9	a	b	7	3b	11	18	6	10	9	10	9	0	0	0	0	33	31	28	42	9	0	8	0					
	b	g		3b	14	9	14	6	3	11	8	0	0	0	0	34	29	38	40	6.5	.5	7	0				1	1
10	a	g	6	2	13	16	13	10	9	11	9	8	6	8	7	29	38	29	37	5	0	6	0				2	
	b	b		2	17	16	14	12	11	10	8	9	8	10	8	33	45	40	45	8	1	8	1					
11	a	b	6	2b	2	6	12	?	?	?	?	0	0	0	0	15	16	26	27	4.5	3.5	2	2			4		1
	b	b		2b	3	12	10	?	?	?	?	0	0	0	0	20	28	31	24	2	4	2	2	1			1	1
				10 year olds.																								
12	a	b	?	3a	—	15	13	13	11	11	11	0	0	0	0	26	32	33	38	6.5	.5	5	1				1	
	b	b		3a	6	16	16	10	8	12	10	8	7	11	8	22	34	41	41	5	0	7	0					1
13	a	b	4	4b	8	18	9	12	10	11	9	7	5	6	4	26	31	33	43	5.5	.5	5	0			1		
	b	b		3b	9	18	4	10	6	10	8	0	0	0	0	29	52	37	50	3	2	2.5	.5			12	2	
14	a	b	5	4a	8	23	24	14	14	11	11	9	7	9	6	41	42	42	43	9	0	9	0					
	b	b		4a	15	15	12	10	10	11	10	10	9	14	10	35	37	46	40	7	0	8	0					
15	a	b	5	6a	17	33	65	13	13	13	12	10	10	9	5	43	47	49	49	12.5	.5	15	0			1		
	b	b		6a	13	15	32	13	12	12	12	9	7	9	7	35	38	40	35	10.5	.5	9.5	2.5					
16	a	g	5	4b	17	16	23	15	14	13	12	14	11	12	10	38	46	52	53	11	1	8	0				1	
	b	g		4b	13	21	11	12	12	15	15	11	10	11	8	34	38	41	48	8	0	6.5	.5				3	
17	a	g	7	3b	12	15	5	4	2	4	3	0	0	0	0	32	45	48	36	4	0	2.5	0				1	2
	b	g		3b	10	9	5	5	4	3	3	0	0	0	0	30	35	35	31	4	0	2.5	0					
18	a	b	7	3b	1	6	15	12	12	14	12	8	8	9	6	30	36	44	42	6.5	1.5	6	1					
	b	g		3b	10	17	5	8	8	11	11	7	6	8	5	28	28	40	39	3	1	4	0	1			1	2
19	a	g	?	2b	—	—	mis.	4	2	5	2	0	0	0	0	21	—	—	—	mis.		1	0					
	b	g		2b	12	11	4	6	5	6	6	0	0	0	0	19	—	—	—	2	0	1	0				5	

Pair	Individual	Sex	Month, Age Grade	Number of Words Containing *a* and *t* Marked	Number of Words Containing *e* and *r* Marked	Number of Misspelled Words Marked	Addition: 1st Trial — Number Done	Addition: 1st Trial — Number Correct	Addition: 2d Trial — Number Done	Addition: 2d Trial — Number Correct	Multiplication: 1st Trial — Number Done	Multiplication: 1st Trial — Number Correct	Multiplication: 2d Trial — Number Done	Multiplication: 2d Trial — Number Correct	A's Marked : Trial 1a	A's Marked : Trial 1b	A's Marked : Trial 2a	A's Marked : Trial 2b	Trial 1 — Opposites Correctly Written	Trial 1 — Opposites Wrongly Written	Trial 2 — Opposites Correctly Written	Trial 2 — Opposites Wrongly Written	Words Wrongly Marked : *a*–*t* Test	Words Wrongly Marked : *e*–*r* Test	Words Wrongly Marked : Misspelled Test	Words Skipped : Opposites Test 1	Words Skipped : Opposites Test 2
20	a	g	9 4b	15	24	13	15	14	15	12	9	4	12	10	47	53	58	64	9.5	2.5	10.5	.5					
	b	g	4b	11	16	7	10	8	8	7	7	4	8	5	36	45	45	43	9	0	9	1					
21	a	g	9 ?	13	14	27	13	13	14	14	15	12	11	10	38	38	41	39	8.5	.5	9	0			2		
	b	b	?	10	12	43	15	14	12	10	11	9	12	9	34	35	39	39	7	1	10.5	.5			1		
22	a	b	11 5a	9	19	2	12	11	12	12	11	10	10	9	38	42	46	45	5.5	.5	2.5	.5					1
	b	b	5a	10	18	5	11	11	11	11	9	7	9	8	29	36	35	34	5.5	.5	4	0	1	1			
	11 year olds.																										
23	a	g	1 5a	19	31	37	14	11	14	14	17	14	18	16	38	50	57	54	12	0	5.5	.5				1	
	b	g	5a	20	37	20	16	15	16	16	15	15	20	19	41	46	50	49	11.5	2.5	7	0				2	1
24	a	b	1 7	—	—	54	18	17	16	15	13	11	17	14	36	39	48	47	11.5	1.5	12.5	.5					
	b	b	7	15	25	35	14	13	14	13	16	13	15	14	45	46	50	52	12	2	11.5	1.5			1		
25	a	b	6 7a	—	—	29	24	23	18	18	16	15	11	9	45	50	55	61	14.5	1.5	11	1				3	
	b	b	6b	—	—	50	20	17	18	18	17	15	12	10	35	38	45	52	10	1	7.5	1.5				1	
26	a	g	10 7b	18	29	91	21	21	20	20	21	19	20	17	60	64	69	67	18.5	.5	20	0			2		
	b	g	7b	19	40	85	19	17	18	17	19	18	16	15	65	60	58	64	19	0	14	0			1		
27	a	g	5 6b	20	44	56	26	25	28	28	23	20	24	22	55	56	60	60	12	0	8	1			1		
	b	g	6b	21	32	38	26	25	24	24	16	14	22	21	66	73	63	60	12.5	.5	9.5	.5			1	1	1
28	a	b	4 3b	—	—	7	8	8	9	8	14	10	14	9	28	—	—	—	7.5	1.5	1	0			2	3	
	b	g	5a	—	—	33	15	9	16	11	12	10	16	13	17	—	—	—	6	0	7	1			1	2	
29	a	b	9 4b	24	31	20	13	11	12	10	9	7	12	11	45	54	51	51	8.5	.5	6	2					
	b	b	5a	18	33	34	15	14	15	15	18	11	20	14	47	42	50	52	11.5	1.5	7.5	.5					2
	12 year olds.																										
30	a	g	1 6a	21	34	22	10	9	13	13	7	5	7	3	47	49	50	55	5.5	.5	8	0				1	
	b	g	6a	17	39	29	11	11	14	13	12	11	9	7	47	50	56	54	8.5	.5	7	0					
31	a	g	? 5a	15	25	30	15	13	16	13	12	8	13	11	45	50	52	53	8.5	1.5	9	0			1	1	
	b	g	5a	12	18	25	15	14	18	18	15	11	15	12	55	61	63	64	11	2	7	1				1	1
32	a	g	4 7a	13	19	47	15	8	14	8	23	5	18	12	53	49	57	62	13	1	15	1	3	5		5	2
	b	g	7a	12	27	46	22	22	18	12	15	14	21	19	48	45	54	59	14	1	15	0			1		4
33	a	b	4 3b	8	22	8	15	12	15	13	12	10	9	5	29	28	34	40	5.5	.5	1	2			1	2	
	b	b	3b	11	14	5	10	8	12	12	9	5	11	10	27	24	32	30	3	1	3	2				1	
34	a	b	4 5b	3	5	17	9	6	6	5	7	4	7	6	19	30	32	31	8.5	.5	10	4					
	b	b	4b	9	12	5	15	13	14	13	9	9	10	9	24	25	25	37	5	2	5	2					
35	a	g	7 6a	16	29	39	19	19	22	21	14	13	16	12	44	48	53	55	10	0	9.5	.5				2	
	b	g	6a	18	29	42	18	17	17	17	14	14	12	11	53	60	63	56	7.5	.5	8	0			1		1
36	a	b	0 5b	17	24	20	4	3	6	5	10	7	8	4	48	55	49	57	8.5	.5	5	1					
	b	g	7a	12	16	21	12	10	11	9	8	5	8	6	38	43	44	41	13	0	2	0					1
37	a	b	7 5a	12	17	0	7	1	5	3	3	2	2	1	22	32	29	30	4	0	2.5	.5		3		1	1
	b	b	4b	16	22	4	14	14	14	14	10	9	10	10	38	46	46	44	2	1	2	0					
38	a	b	6 5a	11	14	6	17	17	15	11	14	10	9	7	28	36	29	32	6.5	.5	2	2			1		
	b	b	6a	12	25	8	17	15	14	12	14	13	14	11	30	30	40	32	8	0	4	2					
39	a	g	11 5b	17	31	33	20	18	22	20	20	16	22	15	38	43	48	53	14	1	13.5	2.5			1	1	1
	b	g	5b	13	22	30	17	14	18	13	15	14	15	13	41	41	42	46	9	0	10	1					1
40	a	b	10 6a	9	21	15	16	13	14	13	10	8	11	10	37	37	43	49	13.5	.5	9.5	2.5	1	1			
	b	b	5b	12	38	48	16	14	14	14	11	8	15	13	43	44	45	48	12.5	.5	10	1			1		
41	a	g	9 7a	16	40	38	16	13	13	13	14	10	16	14	55	59	60	60	14.5	.5	8	1	1		2		
	b	g	7a	17	42	31	14	11	18	17	14	13	16	14	38	56	60	62	12.5	.5	9	0					
42	a	b	11 5	10	18	30	22	—	—	—	—	—	—	9	44	45	52	53	9	1	9	0					
	b	b	6	—	—	28	17								44	52	59	55	10	2	13	0					

Pair	Individual	Sex	Month, Age	Grade	Number of Words Containing *a* and *t* Marked	Number of Words Containing *e* and *r* Marked	Number of Misspelled Words Marked	Addition: Number Done (1st Trial)	Addition: Number Correct (1st Trial)	Addition: Number Done (2d Trial)	Addition: Number Correct (2d Trial)	Multiplication: Number Done (1st Trial)	Multiplication: Number Correct (1st Trial)	Multiplication: Number Done (2d Trial)	Multiplication: Number Correct (2d Trial)	A's Marked: Trial 1a	A's Marked: Trial 1b	A's Marked: Trial 2a	A's Marked: Trial 2b	Opposites Correctly Written (Trial 1)	Opposites Wrongly Written (Trial 1)	Opposites Correctly Written (Trial 2)	Opposites Wrongly Written (Trial 2)	Words Wrongly Marked: *a-t* Test	Words Wrongly Marked: *e-r* Test	Words Wrongly Marked: Misspelled Test	Words Skipped: Opposites Test 1	Words Skipped: Opposites Test 2
			13 year olds.																									
43	a	g	2	6a	17	37	34	17	15	18	18	19	19	17	17	55	62	64	66	17	0	8.5	.5					
	b	g		6a	17	30	20	20	20	17	16	18	17	12	9	48	52	53	56	13	0	10	0					
44	a	b	4	7b	9	18	48	21	21	19	16	17	15	16	16	38	37	38	43	19	1	15.5	1.5			1		1
	b	g		7b	17	35	63	21	19	22	21	20	19	20	16	58	66	68	68	14.5	1.5	11.5	1.5			1		1
45	a	b	4	7a	19	28	43	20	20	14	13	10	7	17	11	37	46	53	52	12	3	14	0					
	b	b		8a	18	43	72	21	21	22	21	26	23	22	21	53	63	55	58	17	2	18	1			1	1	1
46	a	b	9	7a	17	32	33	15	12	9	8	9	7	13	11	34	43	56	50	12	0	7	4			1		
	b	b		6b	13	22	41	14	14	12	11	11	8	9	8	41	42	42	46	7.5	.5	2	2.5				1	
			14 year olds.																									
47	a	b	3	7b	19	26	74	18	16	20	17	14	10	14	8	51	46	52	61	14.5	.5	16	0			1		
	b	b		7b	15	28	60	15	14	15	12	14	8	15	10	40	44	45	44	20	0	14	0			1		2
48	a	b	5	8b	16	33	42	10	9	15	14	15	13	18	18	46	49	60	50	15	0	10	1			1	1	2
	b	b		8b	16	31	41	14	13	18	17	12	12	18	18	50	48	53	54	11.5	.5	9	0				1	3
49	a	g	?	4a	13	12	24	12	12	17	16	9	8	10	6	25	31	40	40	7.5	1.5	8	0					
	b	b		4a	10	13	10	9	9	10	10	misund's'd.				33	29	26	42	2	0	3	1	1		1		
50	a	g	9	8a	12	21	29	22	20	19	16	18	16	21	17	40	40	43	42	12	0	12	0			2		
	b	g		7b	21	30	23	18	13	19	17	16	13	19	13	34	38	50	43	12.5	.5	12	0					

§ 9. *The Reduction of Complex Measures to Single Scores*

For further work it is convenient, and almost imperative, to turn any score involving two or more kinds of quantities, such as amount done and errors, into a single score representing capacity as fairly as may be. It would be possible to so evaluate amounts and errors as to do this with the utmost fairness, but to do so would probably take over a year's labor. I have therefore arbitrarily reduced the complex scores to single scores by the following methods, which are probably innocuous as far as any influence on later deductions goes. I have counted each wrongly marked word in the *a-t* and *e-r* tests as — 2 words marked. Wrongly marked words occur in only one out of ten of the papers. If they were counted as — 3 words marked, as — 1 word marked or not at all, there would be little or no change in the resulting coefficient of correlation. I have in the misspelled word test neglected entirely the words wrongly marked. They occur in over a third of the records, though over two words are marked wrongly by any one person only rarely. If a sl[illegible] tion were made from the number correctly marked, t

each one wrongly marked, it would very slightly raise the coefficient of correlation, perhaps one half of one per cent.

In addition the single score was obtained by adding the number of correctly done units to the total number done, that is by counting a unit correctly done twice as much as one done with an error. So also in multiplication.

In the opposites test the single score was obtained by subtracting 1 from the number of correctly written opposites for each wrong opposite written. No account was taken of words skipped. In the A test 1 a and 2 a were combined into a single measure and also 1 b and 2 b.

The gross complex scores are thus reduced to what may be termed a gross single score, of which the following is a sample:

			Add		Mult.		A test		Opp.	
	Word	Mis.	1	2	1	2	1	2	1	2
2 a g 2 5a	9 23	51	36	39	28	32	86	97	7	8

§ 10. *The Transmutation of Gross Measures into Deviation Measures*

1. To estimate resemblance we have to turn these gross measurements into plus and minus deviations from the central tendency for the age and sex of the individual in question.

2. To prevent the older and consequently more variable children from influencing the result more than the younger,—that is to have each pair of twins weigh alike in estimating the resemblance,—we have to divide each such plus and minus deviation by the variability for its age.

3. To prevent the more variable sex from influencing the results more than the less variable and also to prevent attenuation of the coefficient of correlation by improper comparison of a boy with his twin sister, we have to divide each such plus or minus deviation also by the variability of its sex.

The facts so turn out that 2 and 3 are of no great consequence, however.

These procedures involve the determination of the central tendency and variability for each age and sex from 9 years 0 months through 14 years 11 months (ages were calculated only to a month, 9 years 0 meaning all ages from 9 years 0 days to 9 years 30 days).

I had at hand measurements in each of the tests, in addition to those from the twins, from a large number of children (from 300 to 2,000). My estimates of central tendencies and variabilities are therefore far more accurate than would be possible from calculation the basis of only the 100 individuals of the twins. These measurements were, however, mostly class tests instead

of individual, and were taken in the case of some of the tests by different methods and even by different individuals. They can not be used at their face value, therefore, and the task of finding from a large but not homogeneous set of measurements the most probable central tendencies and variabilities for each age of children tested by the person and method used in the case of the twins, is intricate.

In general my practice was to use all the information I had to determine the *relative* tendencies of different ages, the *relative* variabilities of different ages, the *relative* abilities of the sexes and the *relative* variabilities of the sexes, but to give to the 100 children of the twins the entire decision as to the *absolute* abilities.[1] That is, even if I had 10,000 class measurements with the A test giving values of 50 for 9 years old, 60 for 10 years old, 70 for 11 years old, I should discard them if they made the deviation measures of the 100 twins come out all plus or all minus. I should seek such a scale of central tendencies in each test that approximately 50 per cent. of the twins were plus and 50 per cent. minus.

The main thing then is to get for each sex a series of figures representing the relative abilities of different ages, and a series of figures bearing the same ratios to each other as in the former series, but such that the deviation measures of the twins reckoned from them will be about half plus and half minus.

This latter series of figures was calculated for each test in a table which I shall call the test's 'scale.' A second scale was a series of figures each of which stands to any of the others in the relationship in which the variability of its age stands to that of the other's age.

Thus suppose we have as our scales:

Age		Boys	Boys
Yrs.	Mos.	Central Tendency	Variability
9	5	10	$\frac{1}{5 0}$
12	5	15	$\frac{1}{2 5}$

If now John and James Smith, aged 9 years 5 months, score in addition 11 and 12, and Fred and Frank Jones, aged 12 years 5 months, score 19 and 20, the deviation measures of the four are $+1$, $+2$, $+4$ and $+5$, but, since the variability of the 9 year olds is so much less, the coefficient reckoned from these (.956) would be unduly caused by the older pair. If we divide each deviation measure by its age's variability, or more conveniently multiply it by the reciprocal of its age's variability, we have, $+200$, $+400$, $+100$, $+125$, with $r = .822$.

[1] This makes the obtained correlations too low, in so far as it introduces any error. Whatever error there is, is very small.

A third scale gave for each age in the case of one sex a figure by which to multiply in order to make comparison fair with the other sex. Thus if the variability of girls was 80 per cent. of that of boys we should multiply each girl's deviation by 1.25 if we wished to make our deviations properly commensurate.

In some of the tests it was found that the alterations of variability with age and with sex were so slight as to need no especial allowance. Even in the A, *a-t* and *e-r* tests, where there was the most need of such an allowance, the effect of making it was to alter the coefficients calculated regardless of it only by .002, .032 and .005.

In this report as originally written the derivations of the scales for the A test and for the other tests in essential features were given. Since even when condensed the facts of these derivations fill some 50 pages, mostly of tables, and since their only advantage to the reader would lie in relieving him from taking anything on trust and putting at his service more or less useful statistics concerning some 3,000 children from 8–15 years old, it has been thought best to omit these tables and the commentaries on them.

§ 11. *The Deviation Measures and the Calculation of the Coefficients of Correlation*

After transmuting in accordance with the scales described in § 10, we have for each individual in each trait a measure in terms of his deviation from the central tendency of his age and sex in gross or in terms of the deviation's fractional part of the variability for his age and sex (or an approximation thereto). These deviation measures are given in Table 6.

To measure the probably true general tendency to resemblance of a group we need (1) to measure the general tendency to resemblance actually shown by the figures of the deviation measures and (2) to correct this for the attenuation due to the chance inaccuracy of the deviation measures. (1) is given by the coefficients of correlation between twin and twin of a pair in the A test (1 and 2 combined), in the word test (*a-t* and *e-r* combined), in the misspelled word test, in addition (1 and 2 combined), in multiplication (1 and 2 combined) and in the opposites test (1 and 2 combined). (2) is possible in all cases except the misspelled word test by the proper use of the coefficients of correlation in twins for each single measure, and of the coefficients of correlation between A 1 and A 2 *in the same individuals, a-t* and *e-r in the same individuals,* etc. These correlations for the entire group of twins are given in Table 7. So also are the coefficients as corrected for attenuation.

In the word test I use for the score for the two trials together $2a\text{-}t + e\text{-}r$, since the variability in the *e-r* test is about twice that in *a-t* test.

The combined deviation measure for tests 1, 2 and 3 equals the following: $A1 + A2 + 2a\text{-}t + e\text{-}r + 2$ mis. This gives the three sorts of test approximately equal weights in determining the combined measure and gives the *a-t* test approximately equal weight with the *e-r* test.

The combined measure for tests 4, 5 and 6 equals the following: Add. 1 + add. 2 + mult. 1 + mult. 2 + 3 (opp. 1 + 2). In cases where no score for multiplication was at hand, I used 2 (add. 1 + add. 2) + 3 (opp. 1 + 2).

There is not a perfect correspondence of the combined score for 1, 2 and 3 with the separate scores, owing to the fact that the allowance made for variability in one of the separate scores had not been made when the combined score was calculated.

TABLE 6

Deviation measures of twins

			Test 1			Test 2			Test 3	Combination of 1, 2 and 3	Test 4 Add			Test 5 Mult.			Test 6 Opposites			Combination of 4, 5 and 6
			A1	A2	A1+A2	a-d	c-r	2a-d+c-r	Mir.		1	2	1+2	1	2	1+2	1	2	1+2	
1	a	b	266	246	512	53	76	182	2	992	— 41	— 81	—122	— 50	— 83	—133	— 6	— 14	— 8	— 251
	b	b	356	368	714	90	125	305	22	1625	— 71	— 41	—111	0	— 5	— 5	14	— 16	— 2	— 121
2	a	a	200	220	420	— 15	— 70	—100	402	1491	196	226	422	148	182	330	19	29	48	886
	b	b	40	110	150	— 89	— 77	—243	262	212	216	236	452	88	142	230	49	19	68	886
3	a	a	1	50	51	0	41	41	— 56	99	— 43	33	— 76				8	8	16	200
	g	g	111	190	301	0	54	54	— 26	405	— 27	25	— 2				2	28	26	74
4	a	a				— 22	— 89	—133	— 68	— 402	26	— 4	22				— 21	— 51	— 72	— 112
	b	b				0	24	24	26	100	86	15	51				23	16	7	123
5	a	a	— 64	— 24	— 88	53	76	182	2	261	— 61	— 61	—122				— 16	— 16	— 32	— 540
	b	b	14	76	90	17	52	76	22	306	139	59	198				14	— 16	— 2	390
6	a	a	123	12	135	7	— 62	— 48	8	77	— 13	37	24							
	g	g	63	52	115	81	48	210	8	569	— 43	— 33	— 76							
7	a	a	— 26	— 70	— 96	— 5	— 50	— 45	— 82	— 271	— 43	— 3	— 46				— 18	— 19	— 37	193
	b	b	—217	—208	—425	— 29	— 58	— 96	— 52	— 749	27	— 43	— 16				27	7	34	70
8	a	a	—230	—154	—384	— 53	0	—106	115	— 410	— 15	— 25	— 10	59	13	72	— 1	1	2	68
	b	b	70	— 84	— 14	— 17	48	14	145	301	— 5	15	10	9	73	82	— 19	16	— 3	83
9	a	a	28	2	30	25	30	80	— 54	— 88	11	11	22				40	30	70	254
	b	b	— 75	— 43	—125	40	—115	— 53	— 7	— 222	— 39	11	— 73				6	15	21	— 93
10	a	a	— 26	—148	—174	29	80	30	— 10	— 162	14	24	38	— 4	— 1	— 5	— 4	6	2	39
	g	g	— 94	161	245	100	— 28	210	82	780	54	4	58	48	52	100	20	21	41	281
11	a	a	—294	—169	—463	—105	—111	—321	12	—1166	very low.						— 40	— 49	— 89	
	b	b	—124	—139	—263	— 93	— 59	—225	8	— 752	very low.						— 70	— 49	—119	
12	a	b	—116	— 81	—197		— 57		— 45	— 553	25	5	30				— 9	— 19	— 28	3
	b	b	—196	— 29	—225		— 27		— 15	— 185	— 35	5	— 30				— 9	— 10	— 19	57
13	a	b	—114	— 19	—133	— 27	— 2	— 56	— 76	— 425	— 10	— 10	0				— 8	— 8	— 16	— 48
	b	b	126	81	207	— 17	— 2	— 36	—126	74	— 60	— 30	— 90				— 48	— 38	— 86	— 418
14	a	b	138	63	201	— 29	— 15	68	353	67	7	74		7	— 11	— 4	31	31	62	256
	b	b	28	73	101	41	— 55	47	— 52	112	— 13	— 3	— 16	37	79	116	11	21	32	196
15	a	b	208	193	401	61	145	267	478	1975	47	37	84	47	— 21	26	61	91	152	566
	b	b	38	— 37	1	21	— 55	7	148	311	37	27	64	7	— 1	6	41	11	52	226
16	a	a	52	70	122	48	44	8	—112	246	77	37	114	69	32	101	36	16	52	371
	b	b	— 68	— 18	— 86	8	— 2	14		— 296	27	87	114	29	2	31	16	— 4	12	181
17	a	b	— 54	— 84	—118	— 5	— 65	— 75	—187	— 654	—160	—150	—310				— 26	— 41	— 67	— 621
	g	g	—164	—204	—418	— 25	—124	—174	—187	—1182	—150	—160	—290				— 28	— 41	— 67	— 741

			Test 1			Test 2			Test 3	Combinations of	Test 4 Add.			Test 5 Mult.			Test 6 Opposites			Combination of
			A1	A2	A1+A2	a-t	e-r	2a-t+e-r	Mis.	1, 2 and 3	1	2	1+2	1	2	1+2	1	2	1+2	1, 2 and 3
18	a	b	— 45	59	14	—102	—140	—344	— 34	— 740	20	40	60	3	— 15	— 10	—11	—11	— 22	— 16
	b	g	—244	—134	—378	— 44	— 45	—133	—187	—1056	— 60	— 10	— 70	— 27	— 33	— 60	—46	—26	— 72	— 336
19	a	g									—155	—145	—300				—64	—55	—119	— 957
	b	g									—105	— 95	—200				—44	—55	— 99	— 697
20	a	g	180	280	460	22	19	63	—122	370	64	44	108	— 60	22	— 38	1	32	33	— 177
	b	g	— 10	— 60	— 70	— 16	— 56	— 88	—132	— 614	— 46	— 76	—122	— 80	— 68	—148	21	12	33	— 171
21	a	g	— 60	—140	—200	3	— 75	— 69	18	— 514	34	54	88	80	12	92	11	22	33	279
	b	b	— 27	— 33	— 60	— 14	— 84	—112	235	179	64	— 6	58	39	41	80	— 3	37	34	240
22	a	b	71	85	156	— 25	— 18	— 68	—186	— 541	— 2	8	6	45	17	62	—15	—45	— 60	— 112
	b	b	— 79	—135	—214	— 35	— 48	—118	—156	— 777	— 12	— 12	— 24	— 5	— 3	— 8	—15	—25	— 40	— 152
23	a	g	30	142	172	53	76	182	89	713	11	41	52	113	135	248	47	—22	25	375
	b	g	20	22	42	62	131	255	— 81	392	71	81	152	103	185	288	17	— 2	15	485
24	a	b	9	115	124				332	793	111	71	182	73	135	208	33	53	86	648
	b	b	169	183	352				132	630	31	31	62	123	115	238	33	33	66	498
25	a	b	179	293	472				44	560	214	104	318	133	14	147	57	27	84	717
	b	b	— 41	93	52				254	560	114	104	218	143	34	177	17	—13	4	407
26	a	g	335	338	673	36	41	113	584	2034	121	131	252	181	141	322	95	15	210	1204
	b	g	245	198	443	45	136	226	524	1921	91	81	172	151	81	232	105	55	160	884
27	a	g	231	204	435	57	178	292	248	1498	257	307	564	223	245	468	42	— 9	33	1151
	b	g	511	234	745	65	74	204	168	1452	257	227	484	93	215	308	42	11	53	959
28	a	b							—166		— 90	— 80	—170	67	47	114	—10	—61	— 71	— 270
	b	g							— 26		— 10	20	10	15	76	91	—17	—17	— 34	— 1
29	a	b	201	135	336	107	95	309	— 51	852	— 26	— 46	— 72	— 24	37	13	4	—36	— 32	— 157
	b	b	101	135	236	57	115	229	89	872	24	34	58	106	147	253	24	— 6	18	365
30	a	g	42	13	55	60	81	201	—114	229	— 85	— 15	—100	—107	—136	—243	—39	—10	— 49	— 480
	b	g	52	63	105	26	123	175	— 44	367	— 55	— 5	— 60	3	— 76	— 73	— 9	—20	— 29	— 220
31	a	g	13	10	23	5	0	10	— 43	— 43	— 15	— 5	— 20	— 42	— 13	— 55	—26	— 7	— 33	— 174
	b	g	223	210	433	— 20	— 59	— 99	— 93	49	— 5	65	60	18	17	35	— 6	—37	— 43	— 34
32	a	g	89	138	227	— 60	—133	—253	130	— 19	— 59	— 69	—128	44	54	98	26	46	72	186
	b	g	— 8	78	70	— 18	18	— 18	120	274	151	11	162	54	154	208	36	56	92	642
33	a	b	—274	—187	—461	— 50	— 8	—108	—184	—1057	— 19	— 9	— 28	30	— 70	— 40	—36	—97	—133	— 467
	b	b	—314	—307	—621	— 20	— 88	—128	—214	—1105	—109	— 49	—158	— 60	0	— 60	—66	—77	—143	— 647
34	a	b	—334	—297	—631	—100	—178	—378	— 94	—1575	—139	—179	—318	— 90	— 80	—170	— 6	—27	— 33	— 587
	b	b	—334	—307	—641	— 40	—108	—188	—214	—1445	— 9	— 19	— 28	— 20	— 20	— 40	—56	—57	—113	— 497

			Test 1			Test 2			Test 3	Combination of 1, 2 and 3	Test 4 Add.			Test 5 Mult.			Test 6 Opposites			Combination of 4, 5 and 6
			A1	A2	A1+A2	*a-t*	*e-r*	*2a-t+e-r*	Mis.		1	2	1+2	1	2	1+2	1	2	1+2	
35	a	g	— 27	10	— 17	11	30	52	44	176	80	130	210	21	20	41	1	— 9	— 8	227
	b	g	183	120	303	27	30	84	74	598	50	40	90	31	— 30	1	— 29	— 19	— 48	— 53
36	a	b	198	124	322	39	9	87	— 66	364	—225	—185	—410	— 57	— 96	—153	— 8	— 49	— 57	— 714
	b	g	—127	—210	— 337	— 20	— 76	—116	—133	— 855	— 75	— 95	—170	—112	—110	—222	34	— 76	— 42	— 518
37	a	b	—299	—356	— 655	— 13	—124	—150	very low	—1542	—220	—220	—440	—161	—192	—353	— 50	— 71	—121	—1256
	b	b	— 1	— 46	— 47	27	— 14	40	—230	— 426	— 20	— 20	— 40	— 21	— 22	— 43	— 80	— 71	—151	— 536
38	a	b	—195	—329	— 524	— 22	— 92	—136	—207	—1204	44	— 36	8	33	— 58	— 25	— 29	— 89	—118	— 371
	b	b	—235	—219	— 454	— 12	18	— 6	—187	— 835	24	— 36	— 12	63	32	95	— 9	— 69	— 78	— 151
39	a	g	—161	— 88	— 249	12	34	58	— 36	— 178	67	107	174	91	90	181	25	5	30	445
	b	g	—151	—218	— 369	— 20	— 58	— 78	— 66	— 616	— 3	— 3	— 6	21	0	21	— 15	— 15	— 30	— 75
40	a	b	—121	— 47	— 168	— 46	— 49	—141	—130	— 702	— 20	— 40	— 60	— 44	— 26	— 70	35	— 25	10	— 100
	b	b	9	— 37	— 28	— 16	141	109	200	591	— 10	— 30	— 40	— 34	44	10	25	— 5	20	30
41	a	g	181	116	297	— 9	115	97	24	512	— 17	— 47	— 64	— 20	29	9	38	— 32	6	— 57
	b	g	— 19	136	117	— 16	131	99	— 46	212	— 57	40	— 17	10	29	39	18	— 12	6	40
42	a	b	23	76	99				16	125	107	7	114	22	151	173	— 16	— 7	— 23	218
	b	b	93	166	259				— 4	231	7	— 3	4	— 48	91	43	— 16	33	17	98
43	a	g	181	181	362	7	73	87	— 42	405	— 3	37	34	97	55	152	61	— 30	31	279
	b	g	11	— 29	— 18	7	17	81	—132	— 317	73	3	76	67	— 85	— 18	21	— 10	11	91
44	a	b	—152	—200	— 352	— 52	— 69	—173	177	— 305	80	20	100	72	60	132	76	36	112	568
	b	g	239	227	466	4	51	58	239	990	70	100	170	97	55	152	17	— 13	4	334
45	a	b	— 73	40	32	48	31	127	127	480	70	— 60	10	— 78	20	— 58	— 14	36	22	16
	b	b	258	120	378	38	181	257	417	1884	80	100	180	242	170	412	46	66	112	928
46	a	b	—110	19	— 91	21	59	101	15	154	— 77	—177	—254	—103	— 36	—139	9	— 82	— 73	— 639
	b	b	—100	—161	— 261	— 19	— 41	— 79	95	— 192	— 67	—117	—194	— 73	—106	—179	— 41	—112	—153	— 699
47	a	b	12	59	71	32	— 19	45	415	980	— 25	5	— 20	— 40	— 74	—114	18	38	56	34
	b	b	—118	—181	— 299	— 8	1	— 15	275	269	— 75	— 95	—170	— 60	— 44	—104	78	18	96	14
48	a	b	— 16	19	3	— 2	45	41	92	273	—183	— 83	—266	— 5	60	55	25	— 36	— 11	244
	b	b	14	— 1	13	— 2	25	21	82	217	—103	— 23	—126	— 45	60	15	— 15	— 36	— 51	264
49	a	g	—596	—518	—1114	— 42	—148	—232	—185	—1711	—135	— 45	—180				— 77	— 58	—135	— 765
	b	b	—348	—403	— 751	— 83	—156	—320	—229	—1721	—195	—175	—370				—107	—106	—213	—1379
50	a	g	—406	—520	— 926	— 54	—104	—212	—140	—1426	35	— 35	0	— 6	20	14	— 23	— 23	— 46	124
	b	g	—486	—440	— 926	— 11	— 25	— 3	—200	—1128	— 75	— 25	—100	— 56	— 40	— 96	— 23	— 23	— 46	334

TABLE 7

Data for and results of correction for attenuation

r_g = the raw coefficient from the best obtainable deviation measures.
r_1 = " " " " trial 1 in one twin (a) with trial 1 in the other twin (b).
r_2 = " " " " " 2 " " " " " " 2 " " " " "
Data. r_3 = " " " " " 1 " " " " " " 2 " " " " "
r_4 = " " " " " 2 " " " " " " 1 " " " " "
r_5 = " " " " " 1 with trial 2 in the same individuals.

r_{c4-} = the corrected r, using the formula $r_c = [(r_1 + r_2 + r_3 + r_4)/4]/r_g$.
r_{c2-} = " " " " " " $r_c = [(r_1 + r_2)/2]/r_g$.
r_{c4v} = " " " " " " $r_c = [1.414(r_g) - (r_1 + r_2 + r_3 + r_4)/4]/.414$.
r_{c2v} = " " " " " " $r_c = [1.414(r_g) - (r_1 + r_2)2]/.414$.
R = the probably true r, from the data at hand.

	r_g	r_1	r_2	r_3	r_4	r_5	r_{c4-}	r_{c2-}	r_{c4v}	r_{c2v}	R
1. A test	.634	.597	.616	.643	.626	.875	.71	.69	.67	.70	.69
2. Word test	.569	.595	.428			.655		.78		.71	.71
3. Misspelled	.754										80?
4. Addition	.677	.638	.651	.693	.595	.860	.74	.75	.77	.75	.75
5. Multiplication	.700	.596	.709	.600	.557	.772	.79	.85	.91	.81	.84
6. Opposites	.783	.674	.793	.438	.682	.649				.90	.90?
Comb. of 1, 2 and 3	.697										
Comb. of 4, 5 and 6	.815										

The corrected coefficients for the 9–11 and 12–14 year groups of Table 2 were obtained by the same method.

I choose the 'empirical' or $\surd$ method of correction for the word and opposites tests because we can not be sure that the two trials test the same thing. I choose the correction from r_1 and r_2 rather than from r_1, r_2, r_3 and r_4 for this same reason.

§ 12. *The Sources of Possible Error*

NUMBER OF CASES

The unreliability of the measures of resemblance due to the number of pairs is not large enough to make any of the general deductions of §§ 3–7 insecure. If we use the formula P. E. (of the divergence of the true from the obtained r)

$$= .6745(1 - r^2)/\sqrt{n(1 + r^2)},$$

the P. E. for a raw coefficient of .60 from 50 pairs would be approximately .045. If we use the formula, regarded by some as truer, P. E. (true-obtained r) $= .6745(1 - r^2)/\sqrt{n}$, the P. E. is approximately .06.

Since no claim is made that the general tendency of twins to resemblance in all mental traits is measured, it is needless to ask how unreliable the general tendency to resemblance in these six traits will be as a measure of their tendency to resemblance in the entire group of mental traits as a whole. It may be interesting to note, however, that if these six were a random sampling from mental traits in general and if the corrected coefficients had each a P. E. (true r — obtained r) of .10 or less (as they almost surely do), we

could properly assign as the general tendency of twins to mental resemblance a coefficient of .78 with a P. E. of less than .04.

The chance error due to the small number of measures of each trait in each individual is properly allowed for by the Spearman correction except in the misspelled word test and opposites test. In those two traits it has been allowed for as well as the data at hand permit. The unreliability of the allowance itself is not of great importance. The unreliabilities of the corrected coefficients are little greater than those of the raw coefficients.

The unreliabilities of the central tendencies from which the deviation measures are measured are such that the P. E. (of the divergence of the true from the obtained central tendency) is not over 6 per cent. of the median of the deviation measures. The result of possible variations from the true central tendencies is to make the obtained coefficients slightly too small, *i. e.*, to 'attenuate' them. For the variations will, because of the method used of fitting the central tendencies to the twins, tend to be *toward the obtained central tendencies of the individuals to be correlated.*

The unreliabilities of the variabilities in fractional parts of which the deviation measures are computed need not be considered, since their only influence is to overweight slightly certain ages and to make very slight increases in the chance inaccuracies in the case of the 9 pairs of twins of different sexes. The first influence would very, very slightly increase the variable error of the correlation coefficients; the second would very, very slightly attenuate the coefficients themselves.

On the whole, although an argument based on 1,000 pairs of twins and 1,000 children of each month age would be clearer and more convincing, it could hardly alter in any vital respect any of the general conclusions of §§ 3–7.

UNITS OF MEASURE

In order to have gross measurements perfectly amenable to the later treatment here given, we should have tests so arranged that any unit of achievement called *one* is, under the same conditions, as likely to be achieved as any other unit called *one*. If, for instance, 'to write short after tall' is done by 50 of a hundred 10 year old boys in four seconds, 'to write inside after outside' should also, if it is to be scored the same as 'to write short after tall,' be done by 50 out of a hundred 10 year old boys in four seconds.

The A, *e-r*, addition and multiplication tests approximate somewhat closely to this ideal. The *a-t*, misspelled word and opposites tests do not approximate so closely as I should wish. The distribu-

test of the 24 words, for instance, is such that to mark 11 rather than 10 or 23 rather than 22 means in many cases more difference in efficiency than to mark 10 rather than 9 or 24 rather than 23. Some words in the misspelled word test are obviously much harder to notice than others. So also some words of the opposites test are probably more difficult than others.

We can not therefore be at all sure that if the central tendency for 10 years 4 months in the opposites test is 11, a twin pair scoring 7 and 9 resemble each other to the same extent as a pair scoring 13 and 15. If the central tendency in the misspelled word test is 15 and two members of a twin pair score 50 and 55, they weigh by our calculation far more in determining the general tendency to resemblance than twins scoring 1 and 3. Probably they ought not to.

The influence of the inequalities in the units treated as equal upon the final measures of resemblance is chiefly (1) as an additional source of chance error in the original measures and one possibly not (so far as I can see) fully allowed for in the Spearman correction for attenuation and (2) as a source of unequal weighting of the pairs. The inequalities are not harmful in the way that they would be if the problem was to compare the gross actual measures of individuals, to compare facts rather than relationships.

The nature and amount of their influence could be estimated by an empirical study of the inequality of the units, but only with great labor, which might better be expended in a further investigation with better tests.

THE SELECTION OF TWINS

This research does not pretend to give exact estimates of the general tendency to resemblance in the traits in question of *all* twins. And only one of its lines of argument,—that from the comparison of twin resemblance with sibling resemblance,—depends upon even an approximate measurement of the resemblance of twins as a total group. The selection of twins for measurement was not perfectly at random, but I shall show in the next few paragraphs that the nature of the selection was not such as to damage the argument from the comparison of twin and sibling resemblance.

The selection was made at random as far as conscious choice goes. All pairs of twins heard of were measured and twins were heard of in response to the following written or oral request made of teachers:

> Will you find out if there are any children in your class who have twin brothers or sisters in or out of school? If there are, please record the names, ages, residence, grade and teacher of each such pair of twins upon this sheet,

and after signing your own name and the number of your class, return to the principal's office. If there are none, simply sign your name and return.

TWINS.
First Pair: No. 1. Name
Age
Lives at
Is in grade of P. S.
No. 2. Name
Is in grade of P. S.
Second Pair: No. 1. Name
Age
Lives at
Is in grade of P. S.
No. 2. Name
Is in grade of P. S.
Teacher
Class

But the schools of New York City commonly separate the sexes after the third year of school, and presumably teachers will more often know of the existence of twins when both are in the same school than when they are not. Thus twins of the same sex are probably more frequent in my cases than in general. It is also possible that similar looking twins and twins in the same school grade would be reported relatively more often than less similar looking twins and twins in different grades. To prevent this, as well as to economize effort in finding twins, a careful search was made in each school building. Still this second factor probably has some little weight. The first factor can be estimated. Of the 50 pairs from 9–0 to 15–0 in age, 41 (82 per cent.) are of like sex, whereas of 25 pairs from 6–0 to 9–0 who were also found in the course of the investigation only 19 (76 per cent.) were. We should expect then, in a random sampling of twins 9–14, to find, among 50 pairs, 38 of the same sex.

This difference is not great. Moreover, unlikeness in sex does not imply very much less likeness in mental traits than that manifested by twins of the same sex. The casting out of three records chosen at random from the like-sex pairs and the addition of three records chosen at random from the unlike-sex pairs would not therefore lower the correlation enough to at all vitiate the argument from twin and sibling resemblance. For instance, in the 1, 2 and 3 combination and in the 4, 5 and 6 combination, the r's for the like-sex and unlike-sex groups are as follows:

	Twins of same sex	Twins of different sex
1, 2, 3 combination	$r = .72$	$r = .58$
4, 5, 6 combination	$r = .82$	$r = .79$

The substitution of three unlike-sex pairs for three of the like sex would then alter the coefficients only from .697 and .815 to .680 and .80.

The same can be said of likeness in countenance. Even if once or twice twins were not found because of their unlikeness, the resulting alteration would be slight.

Likeness of degree of advancement in school would be probably more indicative of likeness in the traits measured than likeness in sex or in countenance. Under the conditions of thorough search for twins, it could hardly have operated as an unfair cause of selection in more than four or five pairs of twins, if at all.

It may well be that these two factors would bring the r's for all twins down from the r's obtained from the 50 pairs, say 5 per cent., but they may not have been operative at all and surely were not to any important extent.

The fact that the two members of a twin pair were almost always tested together is a threefold cause of possible error. First the resemblance found may be partly due to resemblances in the conditions of time of day, light, temperature, humidity, and of bodily and mental conditions due to the fact of both twins having been to a party the night before, or having gone without breakfast or the like. The external conditions are not of any considerable consequence, however, for in addition, multiplication and marking misspelled words the time of day has been proved to have zero or very slight influence[1] and differences produced by all such influences as acted in the case of these twin measurements can be shown to be surely very small compared with the differences characteristic of individuals. The bodily conditions which might be similar in twins at any one day and hour have no demonstrable influence on our measures, nor can I demonstrate the absence of influence from them.

Secondly, the resemblance found may be due partly to a greater similarity in the instructions, time given and the like, in the case of a twin pair tested together than would exist for children tested at different times. Of course we were careful to make all instructions and times as uniform as possible, but perfect uniformity is impossible.

Thirdly, the resemblances found may be *less* than the true resemblances in so far as the two trials for any individual were not independent, but were both subject to the same conditions of, say, a headache, or worry or any of the factors causing his normal deviation from his general tendency in the trait in question. The Spearman correction demands independent measures, samples of an

[1] See *Psychological Review*, Vol. VII., pp. 466 ff. and 547 ff.

individual's performances taken at random. When we take two at the same time they give us a chance error not corrected for. The r's between twins are too low, the r's for traits in the same individuals are too high, the r's between twins using both trials are not as much higher than the r's between twins in a single trial as they would be if the two trials were from a random sampling. Or, in plain speech, a twin is as a rule more like his twin brother on the average than he is for any one hour.

It would be the work of months and would require a repetition of tests on the same individuals at different times, which is beyond my power, to evaluate these three possible errors. They may be practically zero or they may be such as to alter the coefficients possibly to 10 per cent. of their amount. The third influence should in my judgment about balance the first two, but I may be wrong.

At all events they do not influence any of the general conclusions of this study except to make the argument from a comparison of twins with siblings less secure in its emphasis.

On the whole, one may feel very sure that the true resemblances of 9–15 year old twins in general in these six traits do not vary by more than a P. E. of ± .05 from the following in each case:

A test	.73
Word test	.75
Misspelled word test	.75
Addition	.75
Multiplication	.80

In the case of the opposites test I should put the facts as .85 ± a P. E. of .05.

CHAPTER III

The Measurements of Physical Resemblances

§ 13. *Gross Measures*

The measurement of resemblances is far easier with physical than with mental traits. The gross measurements are subject to far less chance error; the units of measure are equal; the circumstances of the test make little or no difference; and the determination of central tendencies from which to reckon deviation measures is direct.

I shall consider here the resemblances in general appearance, especially countenance, in eye color, in hair color, in height sitting, in the ratio of height sitting to total height, in width of head, in ratio of width to length of head, in the length of the finger joints and in length of the forearm from the elbow to the tip of the middle finger. All the measurements were taken by the same person, using the same instruments and methods. They could not be made with as much exactitude as one might wish, since the conditions under which the twins were interviewed made elaborate care impossible. They are in every way sufficiently exact for the purpose of this study.

A single measurement only was taken of height, height sitting, and circumference of head; two independent measures (at an interval of twenty minutes) of width and length of head were taken; forearm length was taken for right and left arms; four measures of finger joint length, the first and second fingers on both hands, were taken.

The gross actual measures are given in Table 8. It explains itself except in the case of the measures for height sitting/height, and for eye color. The measure in the former case is really total height (in inches) divided by height sitting (in centimeters). This measure could be gotten more conveniently. To get from it 'height sitting divided by height,' take its reciprocal and divide by 2.405. The measure in the latter is the number of one of twenty-five water color paintings of eye colors, taken empirically from a graded series of eyes chosen so as to represent the eye colors of some hundred students.

TABLE 8

	Sex	Countenance and General Appearance	Hair Color	Eye Color	Height	Height Sitting	Length of Head 1	Length of Head 2	Width of Head 1	Width of Head 2	Cephalic Index 1	Cephalic Index 2	Cephalic Index Av.	Circumference of Head	Height Sitting / ht.	Finger Joint Length 1	Finger Joint Length 2	Forearm Length 1+2	Forearm Length 1	Forearm Length 2	Forearm Length 1+2
1	b	not much	b	7	1295	672	189	189	149	149	788	788	788	550	759	60	69	129	365	360	725
	b		b	7	1303	672	186	186	147	147	790	790	790	543	763	58	66	124	347	347	694
2	g	alike	d b	7	1219	690	177		138		780			505	696	57	62	119	332	335	667
	g		d b	5	1245	697	176		136		773			509	703	58	64	122	340	348	688
5	b	alike	l b	31	1214	630	189	189	151	150	799	793	796	542	759	53	62	115	331	327	658
	b		l b	31	1240	646	190	188	153	154	805	819	812	546	755.5	54	62	116	332	324	656
6	g	alike	d b	3	1245	667	171	171	137	142	801	830	816	502	735	60	65	125	346	343	689
	g		d b	3	1260	671	175	175	145	144	829	823	826	504	739	60	65	125	352	350	702
7	b	not much	d b	10	1265	680	172	172	146	146	849	849	849	520	732	60	67	127	342	348	690
	g		d b	40	1151	618	163	162	136	135	834	839	837	478	733	53	64	117	308	305	613
8	b	alike	d b	8	1372	707	174	174	149	148	856	851	853	525	764	58	69	127	358	367	725
	b		d b	8	1349	690	177	177	152	152	859	859	859	530	769.5	58	70	128	366	368	734
9	b	not much	b	12	1290	684	181	182	141	141	779	775	777	515	743	57	66	123	365	362	727
	g		little lighter	12	1346	686	185	182	140	141	757	775	766	538	773	53	61	114	354	350	704
10	g	not much	lightest	40	1227	669	176		141		801			500	722	56	63	119	317	321	638
	b		flaxen	29	1245	684	178		137		770			498	716.5	59	65	124	336	336	672
11	b	not exactly	b	29	1295	654	182	183	136	136	747	743	745	519	780	61	70	131	364	359	723
	b		b	29	1270	640	183	183	135	135	738	738	738	520	781	59	69	128	353	352	705
12	b	alike	flaxen	29	1283	698	189	184	150	150	794	815	804	538	723.5	55	60	115	342	345	687
	b		flaxen	24	1270	700	195	196	151	151	774	770	773	549	714	59	66	125	342	350	692
13	b	not much	d b	8	1316	687	181		149		823			510	754	63	69	132	364	368	732
	b		b	9	1321	700	177		152		859			530	743	62	67	129	378	385	763
16	g	not alike	l b	40	1290	670	182	184	140	140	769	761	765	525	758	53	60	113	322	322	644
	g		l b	40	1219	653	178	180	136	137	764	761	763	525	735	52	58	110	325	322	647
17	g	alike except eyes	all'ly darker d b	40	1341	681	179	181	140	140	782	773	778	538	775.5	61	67	128	357	353	710
	g			7	1354	682	179	179	141	141	788	788	788	535	781.5	62	68	130	375	370	745

	Sex	Countenance and General Appearance	Hair Color	Eye Color	Height	Height Sitting	Length of Head		Width of Head		Cephalic Index			Circumference of Head	Height Sitting / ht.	Finger Joint Length			Forearm Length		
							1	2	1	2	1	2	Av.			1	2	1+2	1	2	1+2
18	b	not alike	l b	4	1270	663	176	178	148	148	841	831	836	523	754	53	60	113	334	336	670
	g		d b	1	1227	640	174	173	144	146	828	844	836	511	755	54	60	114	336	337	673
19	g		l b	8	1349	730	178	177	149	145	837	842	839	535	727.5	66	75	141	377	374	751
	g		l b	8	1354	727	181	183	149	145	801	792	797	535	733	64	72	136	380	374	754
20	g	alike in most	l red curly	30	1425	732	184	184	141	139	766	755	761	540	769	61	68	129	373	374	747
	g	respects	d b straight	29	1400	731	181	181	139	139	768	768	768	527	754	61	72	133	361	358	719
21	g	not much	d b	12	1328	679	173	173	136	136	786	786	786	505	771	56	65	121	350	349	699
	b		d b	8	1245	649	177	177	138	139	780	785	783	518	755	53	63	116	331	328	659
23	g	alike	d b	29	1372	709	180	180	145	145	806	806	806	538	762	57	66	123	367	367	734
	g		d b	29	1372	708	177	177	147	147	831	831	831	530	763	59	67	126	369	373	742
24	b	alike	flaxen	29	1408	735	189		147		778			520	755	63	71	134	374	379	753
	b		flaxen	29	1372	742	190		149		784			534	728	60	69	129	370	383	753
25	b		b	8	1438	723	185	188	155	153	838	814	826	549	783	65	73	138	377	366	743
	b		b	9	1430	767	180	179	153	153	850	855	850	539	734	64	72	136	378	378	756
26	g	alike	flaxen	33	1542	819	184	184	147	148	799	804	802	560	741	59	67	126	376	380	756
	g		flaxen	33	1537	824	191	191	152	151	796	791	793	580	734	61	68	129	382	383	765
27	g	alike	d b	8	1298	691	169	174	142	144	840	828	834	510	739.5	59	65	124	336	337	673
	g		d b	8	1270	697	170	171	143	143	841	836	839	523	717.5	59	65	124	341	335	676
28	b	not much	b	4	1387	740	189	187	144	143	762	765	763	540	738	59	68	127	364	374	738
	g		b	5	1425	760	176	174	143	143	813	822	817	510	738	62	68	130	375	370	745
29	b	not alike	l b	8	1328	681	179	184	150	150	838	815	827	535	768	63	71	134	376	376	752
	b		b	12.8	1367	724	175	175	147	148	840	846	843	530	743	62	72	134	379	389	768
30	g	very much	chestnut	8	1422	722	177	177	142	146	802	825	814	524	776	61	72	133	382	380	762
	g	alike	chestnut	8	1422	709	176	175	145	145	825	829	827	530	790	63	73	136	390	385	775
31	g	a good deal	b	5	1387	728	174	173	138	136	793	786	789	510	750	59	65	124	358	348	706
	g	alike	l b	40	1349	707	176	176	137	135	778	767	773	501	751	59	65	123	348	342	690

	Sex	Countenance and General Appearance	Hair Color	Eye Color	Height	Height Sitting	Length of Head		Width of Head		Cephalic Index			Circumference of Head	Height Sitting/ht.	Finger Joint Length			Forearm Length		
							1	2	1	2	1	2	Av.			1	2	1+2	1	2	1+2
32	g	alike	d b	3	1410	775	177	176	144	145	814	824	819	515	716	60	70	130	375	375	750
	g		d b	3	1422	770	175	173	143	145	817	838	828	513	727	60	70	130	378	377	755
34	b	not much	d b	7	1321	688	182	182	138	138	758	758	758	520	756	61	69	130	368	368	736
	b		b	7	1354	721	188	187	135	137	718	733	725	528	739	68	75	143	367	371	738
35	g	not exactly	b	12	1290	643	171	174	141	141	825	810	817	510	790	58	63	121	358	358	716
	g		b	12	1308	640	175	176	137	137	783	778	780	500	805	54	63	117	353	353	706
36	b	not much	b	4	1354	691	183	182	144	143	787	786	786	532	771	60	69	129	377	370	747
	g		b	lar. 4	1367	695	175	174	146	146	834	839	837	530	774	65	72	137	387	372	759
37	b	not much	b	28	1435	734	178	178	146	145	820	814	817	530	770	61	69	130	384	382	766
	b		d b	9.12	1430	720	177	177	147	147	830	830	830	528	782	63	73	136	387	382	769
38	b	not alike		32	1440	747	176	175	145	145	825	829	827	520	759	61	69	130	372	372	744
	b			12	1463	760	175	177	149	149	851	842	846	530	758	61	70	131	378	378	756
40	b	not much	red	29	1397	724	173	179	147	142	850	850	850	507	760.5	64	72	136	384	378	762
	b		redder	28	1435	764	173	179	147	142	793	793	793	507	739.5	67	75	142	404	395	799
41	g	not much	d b	4	1410	753	179	179	150	152	838	838	838	539	737	61	68	129	368	354	722
	g		b	4	1506	791	179	178	150	150	849	843	846	560	750	66	75	141	384	372	756
43	g	not exactly	flaxen	29	1486	765	184	182	144	143	783	783	783	535	765	67	74	141	396	389	785
	g		chestnut	29	1468	756	184	183	144	143	786	786	786	536	765	64	73	137	387	393	780
44	b	not alike	brown	7	1384	759	177	176	138	139	779	790	785	510	692	67	74	141	430	425	855
	g		flaxen	12	1430	760	165	162	137	133	830	821	826	490	741	61	69	130	367	370	737
45	b	somewhat	b	29	1506	769	168	168	151	151	899	899	899	512	771	61	72	129	410	410	747
	b		b	8	1519	781	173	174	148	149	855	856	856	532	766	68	76	137	415	413	759
47	g	alike	d b	8	1626	848	178	178	148	148	832	832	832	527	755	67	78	145	440	440	880
	g		d b	8	1595	841	176	177	146	146	830	825	828	525	747	67	78	145	445	447	892
50	g	alike	chestnut	4	1565	808	180	180	151	150	839	833	836	554	762	67	77	144	411	404	815
	g		chestnut	4	1557	780	179	179	150	150	838	838	838	545	786	66	75	141	402	406	808

§ 14. *Deviation Measures*

The scales of probable central tendencies from which deviation measures were reckoned are summarized in Table 9. For the derivations of these scales space is lacking. They are not so reliable as I should wish them to be, but the resulting effect on the calculations of resemblance involves only a trifling variable error. No allowance was made for sex or age differences in variability except in the case of height. Each deviation measure for height was transmuted into the fractional part which it was of the variability of the age and sex to which it belonged. The measures of variability used were those given by Boas in the Report of the U. S. Commissioner of Education, 1896–7, pp. 1555–1556. The deviation measures are given in Table 10.

TABLE 9

Scales of probable central tendencies for twins in physical traits

Years	Months	Height B	Height G	Width of Head B and G	Circum. of Head B and G	Finger Joint Length B and G 1	Finger Joint Length B and G 2	Finger Joint Length B and G 1 and 2	Forearm Length B and G
9	0–2			144.5	516	58	65	123	
	3				519				
	5–6	1267	1259						690
	6				520		66	124	
	9				522	58.5	66.5	125	
10	0			145.0	523				
	3				525	59	67	126	
	5–6	1316	1309						705
	6				526				
	9				527	59.5	67.5	127	
11	0			145.5	528	60	68	128	
	3				530	61		129	
	5–6	1362	1364						730
	6			146.0					
	9				531		69	130	
12	0								
	3				532	61.5	69.5	131	
	5–6	1405	1423						755
	6			146.5		62	70	132	
	9				533		71	133	
13	0			147.0					
	3				534	63		134	
	5–6	1458	1485						780
	6			147.5		64	72	136	
	9			148.0	535		73	137	
14	0			148.5			74	138	
	3				536		75	139	
	5–6	1521	1533	149.0					810
	6					65		140	
	9				537	66		141	

For height sitting take .523 × height.

For cephalic index take (A) 813 for all or (B) 79 for 9 years, 80 for 10 years, 81 for 11 years, 82 for 12 years and 83 for 13 and 14 years. By (A) $r = .738$; by (B) $r = .741$.

For height sitting/height take 755 for all (the gross measure for this ratio was gotten, for the sake of convenience, by dividing the height in inches by the height sitting in centimeters).

For separate arm lengths (1 and 2) take .5 × scale for 1 + 2.

For height, height sitting and forearm length the scales used were by interpolation made into scales fitted to single months.

TABLE 10

Deviation measures in physical traits

		Height	Height Sitting	Width of Head	Cephalic Index	Circumference of Head	Height Sitting/ht.	Finger Joint			Forearm		
								1	2	1+2	1	2	1+2
1	b	116	17	45	*—25*	32	4	2	4	6	25	20	45
	b	138	17	25	*—23*	25	8	0	1	1	7	7	14
2	g	*— 76*	40	*— 65*	*—33*	*—14*	*—59*	*—1*	*—3*	*— 4*	*—11*	*— 7*	*—18*
	g	*— 5*	47	*— 85*	*—40*	*—10*	*—52*	0	*—1*	*— 1*	*— 3*	+ 6	+ 3
5	b	*—103*	*—25*	60	*—17*	24	4	*—5*	*—3*	*— 8*	*—11*	*—14*	*—25*
	b	*— 32*	*— 9*	90	*— 1*	28	0.5	*—4*	*—3*	*— 7*	*—10*	*—17*	*—27*
6	g	*— 38*	8	*— 52*	3	*—18*	*—20*	2	0	2	1	*— 1*	0
	g	3	12	*— 2*	13	*—16*	*—16*	2	0	2	7	6	13
7	b	*— 5*	17	13	36	0	*—23*	2	2	4	*— 3*	4	1
	g	*—292*	*—41*	*—117*	24	*—42*	*—22*	*—5*	*—1*	*— 6*	*—37*	*—39*	*—76*
8	b	276	43	40	40	6	9	0	4	4	13	22	35
	b	214	31	75	46	10	14.5	0	5	5	21	23	44
9	b	41	17	*— 40*	*—36*	*— 6*	*—12*	*—1*	0	*— 1*	19	16	35
	g	114	22	*— 45*	*—47*	17	8	*—5*	*—5*	*—10*	8	4	12
10	g	*— 97*	19	*— 87*	*—12*	*—20*	*—33*	*—2*	*—3*	*— 5*	*—29*	*—24*	*—53*
	b	*— 70*	28	*— 77*	*—43*	*—22*	*—38.5*	1	*—1*	0	*—10*	*— 9*	*—19*
11	b	65	*—10*	*— 88*	*—68*	*— 1*	25	3	4	7	18	14	32
	b	*— 3*	*—24*	*— 98*	*—75*	0	26	1	3	4	7	7	14
12	b	38	8	*— 9*	*— 9*	12	*—31.5*	*—3*	*—6*	*— 10*	*—11*	*— 7*	*—18*
	b	5	10	*— 40*	*—40*	23	*—41*	1	*—1*	0	*—11*	*— 2*	*—13*
13	b	11	1	43	10	*—15*	*— 1*	4	2	6	13	17	30
	b	24	14	73	46	5	*—12*	3	0	3	27	34	61
16	g	49	11	*— 53*	*—48*	*— 1*	3	*—6*	*—7*	*—13*	*—30*	*—30*	*—60*
	g	231	*— 6*	*— 88*	*—50*	*— 1*	*—20*	*—7*	*—9*	*—16*	*—27*	*—30*	*—57*
17	g	55	*— 9*	*— 55*	*—35*	11	20.5	2	0	2	3	*— 1*	2
	g	88	*— 8*	*— 45*	*—25*	8	26.5	3	1	4	21	16	37
18	b	*—136*	*—29*	25	23	*— 4*	*— 1*	*—6*	*—7*	*—13*	*—20*	*—18*	*—38*
	g	*—230*	*—52*	*— 5*	23	*—16*	0	*—5*	*—7*	*—12*	*—18*	*—17*	*—35*
19	g	93	40	37	26	9	*—27.5*	7	8	15	24	22	46
	g	105	37	*— 3*	*—16*	9	*—22*	5	5	10	27	22	49
20	g	231	38	*— 55*	*—52*	13	14	1.5	.5	2	17	18	35
	g	171	37	*— 65*	*—45*	0	*— 1*	1.5	3.5	5	5	2	7

		Height	Height Sitting	Width of Head	Cephalic Index	Circumference of Head	Height Sitting / ht.	Finger Joint 1	Finger Joint 2	Finger Joint 1+2	Forearm 1	Forearm 2	Forearm 1+2
21	g	0	—15	— 95	—27	—22	16	—3.5	—2.5	— 6	— 6	— 7	—13
	b	—213	—37	— 70	—30.5	— 9	0	—6.5	—4.5	—11	—25	—28	—53
23	g	62	8	— 10	— 7.5	10	7	—3	—2	— 5	7	7	14
	g	62	7	10	18	2	8	—1	—1	— 2	9	13	22
24	b	156	35	10	—35	— 8	0	3	3	6	14	19	33
	b	68	42	30	—29	6	—27	0	1	1	10	23	33
25	b	176	10	80	13	19	28	4	5	9	11	1	13
	b	157	54	70	37	9	—21	3	4	7	12	13	25
26	g	367	93	12	—11	29	—14	—2	—2	— 4	6	11	17
	g	355	98	52	—20	49	—21	0	—1	— 1	12	14	26
27	g	34	—22	— 30	21	—20	—15.5	—2	—3	— 5	—28	—27	—55
	g	6	—16	— 30	26	—17	—37.5	—2	—3	— 5	—23	—29	—52
28	b	74	31	— 25	—50	10	—17	—2	0	— 2	1	11	12
	g	159	49	— 30	4	—10	—17	1	0	1	12	7	19
29	b	—109	— 38	37	13	4	13	2	2	4	7	8	15
	b	— 19	5	12	30	— 1	—12	1	3	4	10	21	31
30	g	44	— 11	— 25	1	— 7	21	0	3	3	9	8	17
	g	44	— 24	— 15	14	— 1	35	2	4	6	17	13	30
31	g	— 87	— 17	— 95	—24	—22	— 5	—3	—4	— 7	—20	—29	—49
	g	—171	— 38	—105	—40	—31	— 4	—4	—4	— 8	—30	—35	—65
32	g	— 18	33	— 20	6	—17	—39	—1.5	.5	— 1	— 1	— 1	— 2
	g	9	28	— 25	15	—19	—28	—1.5	.5	— 1	2	1	3
34	b	—178	— 44	— 85	—55	—12	1	— .5	— .5	— 1	— 8	— 8	—16
	b	—104	— 11	—105	—88	— 4	—16	6.5	5.5	12	— 9	— 5	—14
35	g	—318	—106	— 60	4	—22	35	—4	—7	—11	—21	—21	—42
	g	—278	—109	—100	—33	—32	50	—8	—7	—15	—26	—26	—52
36	b	—120	— 34	— 30	—27	1	16	—1	0	— 1	5	— 1	4
	g	—131	— 36	— 5	23.5	— 1	19	4	3	7	15	1	16
37	b	45	— 6	— 15	4	— 2	15	—1	—1	— 2	5	3	8
	b	34	— 20	0	17.5	— 4	27	1	3	4	8	3	11
38	b	65	10	— 20	13.5	—12	4	—1	—1	— 2	— 6	— 6	—12
	g	115	23	20	31	— 2	3	—1	0	— 1	0	0	0
40	b	— 66	— 22	0	37	—26	5.5	2	1	3	2	— 4	— 2
	b	15	18	— 50	—20	—26	15.5	5	4	9	22	13	35
41	g	— 72	— 2	30	25	63	—18	—1	—3	— 4	—13	—27	—40
	g	132	36	40	31	27	—15	4	4	8	3	— 9	— 6
43	g	33	— 2	— 25	—30	2	10	5	3	8	9	3	12
	g	— 4	— 11	— 45	—27	3	10	2	2	4	0	7	7
44	b	—240	— 1	— 90	—28	—24	—63	4	3	7	41	37	78
	g	—100	— 14	—125	13	—44	—14	—2	—2	— 4	—22	—18	—40
45	b	104	9	35	86	— 2	16	—3	—2	— 5	—12	—18	—30
	b	130	21	10	43	— 4	11	2	1	3	— 2	—16	—18
47	g	205	58	— 10	18.5	— 8	0	3	3	6	39	39	78
	g	150	51	— 30	14.5	—10	— 8	3	3	6	44	46	90
50	g	52	1	10	23	18	7	1	2	3	3	— 4	— 1
	g	33	— 27	5	25	9	31	0	0	0	— 6	— 2	— 8

§ 15. *The Measures of Resemblance*

The raw coefficients of correlation, and the corrected coefficients where correction for attenuation was made, are given in Table 11. The correction in the case of height, height sitting, their ratio and the circumference of head, would obviously be very, very slight.

That it was just to compare (in § 6) the r's in mental traits of the 50 pairs with the r's in physical traits of the 39 pairs is shown by Table 12.

That the tendency of the method of discovery of twins to obtain more twins of the same sex than exist among twins as a whole, can make little difference in the validity of the r's is evident from the fact that there is only one more same-sex pair in the 39 than would be given by the proportion among 6–9 year olds.

TABLE 11

The resemblances in physical traits

	r obtained	R corrected for attenuation	r_1	r_2	r_3	r_4	$r1+2$	r single	r same
Height	.775								
Height sitting	.834								
Ht. sitting/height	.758								
Width of head	.824	.86	.798	.784			.817	.791	.93
Circum. of head	.745								
Cephalic index	.740	.76	.726	.696			.738	.711	.954
Finger joint length	.645	.705	.576	.719	.661	.525	.645	.620	.880
Forearm length	.661	.715	.608	.673			.661	.640	

TABLE 12

The resemblance in mental traits of the 39 pairs measured also in physical traits compared with the resemblance of all the twins

The raw coefficients are used in the comparison.

	39 pairs	50 pairs	Difference
A test	.575	.634	— .059
Word test	.579	.569	+ .010
Misspelled	.760	.754	+ .006
Combination of 4, 5 and 6	.815	.815	.000

§ 16. *The Problem of the Form of Distribution of Resemblance in Twins*

It has been supposed by embryologists and others who have studied twins, apparently somewhat generally, that twins are divided distinctly into two classes: Those very closely alike, and those much less closely alike,—in fact, little, if any, more alike than ordinary siblings.

This division into two species has, again, commonly been supposed

by embryologists to be the consequence of the existence of two modes of genesis of twins:—by the division of one ovum after fertilization, and by the simultaneous development of two ova. These two common opinions are clearly stated by H. H. Wilder as follows:

"*Definitions of Duplicate and Fraternal Twins.*—These considerations, together with the distinctions made at the beginning of the article, will enable us to formulate distinctive definitions of the two forms of twins, as follows:

"I. *Fraternal Twins.*—Either of the same or opposite sex and bearing no closer physical resemblance than is usual in children of the same family. These probably originate as two separate eggs, and any intimacy of association during intra-uterine life (which is never as close as in duplicates) may be attributed to the crowding within narrow limits to which they are necessarily subjected and for which no adequate provision is made such as occurs in mammals in which multiple births are the rule and not the exception.

"II. *Duplicate Twins.*—Invariably of the same sex and exact or approximately exact physical equivalents of one another, especially in youth, before the modifying influences of environment and habit have had much opportunity to affect them. During intra-uterine life these are more intimately associated than are other twins, and in rare cases this association is of so close a character as to

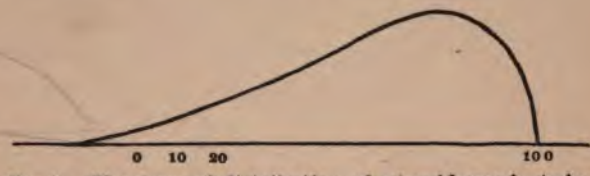


FIG 7. The form of distribution of resemblance in twins.

result in the production of compound monsters. All such cases, whether separate or united, may be referred to one and the same cause, that of some division in the fertilized egg, presumably that of the first cleavage nucleus, in such a fashion as to result in the formation and development of two embryonal areas upon a single blastodermic vesicle."[1]

The evidence in the cases of the thirty-nine pairs of twins from whom we have extended physical measurements gives no reason for acceptance of the hypothesis of two such distinct groups of twins. The form of distribution of resemblance in twins as a whole seems rather to be unimodal, with a high mode (at about .80) and a long skewness on the negative side, such as allows of some twins being

[1] *American Journal of Anatomy*, 1904, Vol. III., p. 392.

little more alike than children of the same age picked at random (see Fig. 7).

I am not competent to judge concerning the general biological evidence which makes it probable that twins should represent two distinct modes of fertilization and genesis, but it seems to laymen in biology rather far-fetched. There is surely no need of it to explain the facts of the likeness of twins, for the closest likeness grades off gradually into notable difference as one ranks twin pairs by their resemblance. So far as the distribution of resemblance in twins goes, it makes probable a single mode of genesis, and such a one as would permit wide variability in the amount of likeness of the two members of a twin pair, but at the same time tend more strongly to produce *in any one trait,* nearly perfect resemblance, than any other degree of resemblance.

So far, I have tacitly treated the group of twins as a single group, homogeneous with respect to resemblance. It might have been the case, however, that they were really a mixture of two distinct groups, one composed of pairs displaying very close resemblance, the other of pairs displaying very little. Or, there might be three distinct groups, one of pairs almost exactly alike, one of pairs moderately alike, and one of pairs actually dissimilar. In no case would the arguments on the influence of the environment and of original nature be seriously affected, but if there were two or more distinct species of twins it would have been more correct and more enlightening to have made calculations of every kind separately for each such group. §§ 17–18 will justify my previous procedure by showing that as regards resemblance twins are more nearly a single homogeneous group than a mixture of two or more.

The detailed discussion of the form of distribution of the resemblances of twins will follow this order of topics:

1. The means of measuring the resemblance of a single pair.
2. The calculation of the detailed resemblances of each pair of twins.
3. The calculation of the general tendency to resemblance in each pair of twins.
4. The distribution of these general tendencies to resemblance.
5. The distribution of resemblances in the case of single traits.
6. The views of other investigators.
7. The most probable mode of genesis of twins.

§ 17. *Means of Measuring the Resemblance of a Single Pair*

Our problem is to measure accurately the resemblance found in each pair of twins, and so to ascertain the form of distribution of

the group with respect to resemblances. Suppose, for instance, that of forty twins, we found twenty to resemble each other practically perfectly, the coefficients being: 92, 93, 94, 94, 94, 95, 95, 95, 95, 95, 96, 96, 96, 97, 97, 97, 97, 98, 99 and 99, and the other twenty to resemble each other as follows: 17, 18, 24, 29, 32, 37, 37, 38, 40, 41, 41, 41, 42, 42, 44, 45, 46, 46, 51 and 62. It would be clear that there were two distinct types of twins.

To measure accurately the resemblance of an individual pair is, however, very difficult. The most serviceable measure which I am able to devise for a single pair in any trait is the Pearson coefficient, using each individual twice in the calculation. That is, if the deviation measures are:

First member of pair — 6,
Second member of pair — 3,

then the $\Sigma xy = 18 + 18$,
$\Sigma x^2 = 36 + 9$,
$\Sigma y^2 = 9 + 36$,
and $r = \frac{36}{45} = .80$.

The objections to this measure are that when both members of the pair are near the central type, it may misrepresent the real relationship and will be much distorted by accidental errors in the deviation measures of an individual. Thus, suppose that in a case where the variability of the trait is 10, two twins score — 1 and + 2. Their r as calculated will be + .80, but they are really very much more alike than this figure would lead us to think. Suppose by accidental error the first member scored — 2 instead of — 1; then their r is — .80. Suppose him to score + 1; the resemblance is + .80.

I shall also use as a measure of the resemblances of a single pair the difference between their measures. The objection to this measure is that its meaning in any case depends in part upon the amount and direction of the deviation measures of which it is the difference. Thus, whether two twins score + 40 and + 50 or 0 and 10 the measure of difference is the same. But the former means probably a greater resemblance.

In calculating both measures and also the median deviation (the so-called 'probable error') from the central tendency in each trait, we have at hand information sufficient to interpret the resemblances, provided there is no attenuation by inaccuracy in the original measures. In the case of width of head and cephalic index, we know this to be practically zero. In height, height sitting, the ratio of height sitting to total height and circumference of head, we have every reason to believe it to be little. It should also influence

any two groups of twins in the same way except by chance, and chance differences would be negligible in the case of groups of twenty.

So if we measure the total resemblance in each pair of twins by their resemblances in these six traits and distribute the total resemblances, we shall have a closely accurate answer to the question of the existence of two or more species of resemblance in twins. For whatever is the form of distribution of the resemblance of twins, it should be, in general form, substantially identical with the distribution of the resemblance calculated from six such traits.

There is, however, one difficulty in the interpretation of the facts, —a peculiar difficulty, in that while it makes it somewhat hard to show at all elegantly the exact form of distribution of the general tendency to resemblance, it also of itself disproves the existence of one of the two species into which twins have been supposed to be divided: namely, identical twins, very closely alike in original nature, and equally alike in all respects.

The difficulty is the specialization of resemblances,—the fact that even the most similar twins differ markedly in some traits; the fact that in the same pair there is great variability of resemblance as we pass from one trait to another; that, for instance, twins indistinguishable in countenance, eye color and hair color may be clearly unlike in cephalic index. Such specialization makes it less easy to measure the general tendency to resemblance in any pair, and so makes the proof of the form of distribution of resemblance less elegant. Such specialization disproves the existence of the identical-twins species, because in nineteen pairs out of twenty, and probably in ninety-nine pairs out of a hundred, will be found some traits in which nothing approaching identity exists. The most identical twins will in *some* respect be less like each other than ordinary siblings.

Facts to prove the existence of this specialization of resemblance will be given clearly by themselves in § 22. Many of the same facts will appear incidentally in the course of the present attempt to measure the resemblance of each individual pair of twins.

§ 18. *The Resemblances of Single Pairs and Their Distribution*

The facts of individual-pair resemblance in the six traits chosen are given in Table 13. For each pair in each trait is given the r, the amount of the deviation from the central tendency of that one of the twins who deviated from it most (this is given in each case as a multiple of the median deviation for the trait in question), and the difference between the two twins' measures (this is given in each

TABLE 13

	Height			Height Sitting			Height Sitting/ht.			Circumference			Width			Width/length		
	r	*d*	dif.	*r*	*d*	dif.	*r*	*d*	dif.	*r*	*d*	dif.	*r*	*d*	dif.	*r*	*d*	dif.
1	98	1.7	.4	100	.8	0	80	.5	.5	97	3.2	1.0	85	1.1	1.0	100	1.0	.2
2	14	1.0	1.3	98	2.1	.6	100	3.7	.9	95	1.4	.6	96	2.1	1.0	98	1.6	.6
5	57	1.3	1.3	64	1.1	1.4	24	.3	.4	99	2.8	.6	92	2.2	1.5	12	.7	1.3
6	—16	.5	.7	92	.6	.3	98	1.3	.5	99	1.8	.3	8	1.3	2.5	42	.5	.8
7	8	3.7	5.1	—71	1.9	4.6	100	1.4	.1	0	4.2	6.0	—22	2.9	6.5	92	1.4	1.0
8	97	3.5	1.1	95	2.0	1.0	89	.9	.7	80	1.0	.7	83	1.9	1.8	99	1.8	.5
9	64	1.4	1.3	97	1.0	.4	—92	.8	2.5	63	1.7	3.3	100	1.1	.3	97	1.8	.9
10	95	1.2	.5	93	1.3	.7	99	2.4	.7	100	2.2	.3	80	2.0	2.0	52	1.7	2.6
11	— 9	.8	1.2	71	1.1	1.1	100	1.6	.1	0	.1	.1	99	2.4	.5	100	3.0	.6
12	27	.5	.6	97	.5	.2	97	2.5	1.2	78	2.3	1.6	98	1.5	.5	43	1.6	2.6
13	94	.3	.2	14	.6	1.0	17	.8	1.4	—60	1.5	2.9	87	1.8	1.5	41	1.8	3.0
16	41	2.9	3.3	—84	.5	1.4	—29	1.3	2.9	100	.1	0	89	2.2	1.9	100	2.0	.2
17	91	1.1	.6	99	.4	.1	97	1.6	.8	95	1.1	.4	98	1.4	.5	95	1.4	.9
18	86	2.9	1.7	85	2.4	1.8	0	.1	.1	47	1.6	1.7	—38	.6	1.5	100	.9	0
19	100	1.3	.2	100	1.8	.2	97	1.7	.7	100	.9	0	—16	.9	2.0	—89	1.0	3.5
20	96	2.9	1.1	100	1.7	.1	—14	.9	1.9	0	1.3	1.9	99	1.6	.5	99	2.1	.6
21	0	2.7	3.8	70	1.7	1.8	0	1.0	2.0	70	2.2	1.9	95	2.4	1.3	99	1.2	.3
23	100	.8	0	99	.4	.1	99	.5	.1	38	1.0	1.1	—100	.3	1.0	—71	.7	2.1
24	73	2.0	1.6	98	1.9	.6	0	1.7	3.4	—96	.8	2.0	60	.8	1.0	99	1.4	.5
25	99	2.2	.3	36	2.5	3.5	—96	1.8	6.1	77	1.9	1.4	99	2.0	.5	62	1.5	2.0
26	100	4.6	.2	100	4.5	.4	92	1.3	.9	88	4.9	2.9	44	1.3	2.0	84	.8	.8
27	33	.4	.5	96	1.0	.5	71	2.4	2.8	99	2.0	.4	100	.8	0	98	1.0	.4
28	77	2.0	1.5	90	2.2	1.4	100	1.1	0	—100	1.0	2.9	98	.8	.3	—16	2.0	4.5
29	34	1.4	1.6	—26	1.7	3.4	—100	.8	3.1	—47	.4	.7	59	.9	1.3	73	1.2	1.4
30	100	.6	0	76	1.1	1.0	88	2.2	1.8	28	.7	.9	88	.6	.5	14	.6	1.1
31	81	2.1	1.5	75	1.7	1.7	98	.3	.1	94	3.1	1.3	99	2.6	.5	88	1.6	1.3
32	—80	.2	.5	97	1.5	.4	95	2.4	1.4	99	1.9	.3	95	.6	.3	69	.6	.8
34	87	2.2	1.3	46	2.0	3.4	—12	1.0	2.1	60	1.2	1.1	95	2.6	1.0	90	3.5	2.8
35	100	4.0	.7	100	5.0	.2	94	3.1	1.9	85	3.2	1.4	88	2.5	2.0	—24	1.3	3.1
36	99	1.6	.2	100	1.6	.2	99	1.2	.4	—100	.1	.3	32	.8	1.3	—99	1.1	4.2
37	94	.6	.2	55	.9	1.1	85	1.7	1.5	80	.4	.3	0	.4	.8	44	.7	1.1
38	86	1.5	.9	73	1.0	1.0	96	.3	.1	82	1.2	1.4	—100	.5	2.0	73	1.2	1.5
40	—43	.8	1.4	—98	1.0	3.2	63	1.0	1.3	100	2.6	0	0	1.3	2.5	—84	1.5	4.8
41	—84	1.7	3.6	—11	1.6	3.0	51	1.1	1.6	72	6.3	5.1	96	1.0	.5	98	1.2	.5
43	—24	.4	.7	35	.5	.7	100	.6	0	92	.3	.1	97	1.1	.5	99	1.2	.3
44	71	3.0	2.5	14	.6	1.2	42	4.0	6.1	84	4.4	2.9	94	3.1	1.8	—76	1.1	3.4
45	97	1.6	.5	73	1.0	1.0	93	1.0	.6	80	.4	.3	53	.9	1.3	80	3.4	3.6
47	96	2.6	1.0	99	2.6	.6	0	.5	1.0	97	1.0	.3	60	.8	1.0	97	.7	.3
50	89	.7	.3	— 7	1.2	2.2	45	1.9	3.0	80	1.8	1.3	80	.3	.3	100	1.0	.2

case as a multiple of the median difference of *all the twins* in the trait in question).

Thus, in the first line of the table, the first three figures mean: The resemblance in height of the twins of pair 1 is, by the Pearson formula, 98; one of the twins was 1.7 × the median deviation (or P. E.) away from the central tendency; the difference between the two twins was .4 as great as the median difference in the whole group of twins. From the record of pair 1 in height, we see that the high *r* is corroborated by the low difference (.4 × median difference of twins would be in fact about .2 × the median difference of unrelated children of the same age and sex). The value of the deviation column may be noted from pair 32 in height. The record is — 80; .2; .5. Since the two twins were both very close to the central tendency (within .2 the median deviation), the — 80 is misleading, and should be considered in the light of the small difference (.5 × that of twins in general or about .25 × that of two children of the same age and sex picked at random).

From these facts of Table 13, I calculate the distribution of the

averages[1] of resemblance to be as in Table 14, column A, and of the medians of resemblance to be as in column B. The total distribution of the fairly accurate *r*'s is given in column C, the total distribution of *all* the *r*'s is given in column C (1) and the total distribution of the differences in column D.[2]

There is no sign in any of these of a sharp separation into a group of 'duplicate twins' with *r*'s approaching 100 and differences approaching 0, and a group of 'fraternal twins' with *r*'s approaching 40 and differences centering around a point well above the median difference for twins. Nor can I make the total distribution split up into two such species as the common opinion posits, even by suppos-

TABLE 14

The distribution of resemblances in twins: in ht., ht. sitting, ht. sitting/ht., circumference of head, width of head and cephalic index.

	Measured in Individual Coefficients				Measured in Differences			
	A	B	C	C(1)	D			
	Average of corrected coefficients of each pair	Median of corrected coefficients of each pair	All accurate coefficients	All coefficients	In Multiples of the Median Difference of all Twins			
					Fine Grouping		Coarse Grouping	
					4.0 +	10		
— 1.00 to — .91			7	10	3.8–3.9	1		
— .90 to — .81			4	4	3.6–3.7	2		
— .80 to — .71			2	3	3.4–3.5	5		
— .70 to — .61			1	1	3.2–3.3	4	6.4–6.7	1
— .60 to — .51					3.0–3.1	5	6.0–6.3	3
— .50 to — .41			1	2	2.8–2.9	7	5.6–5.9	
— .40 to — .31			2	2	2.6–2.7	2	5.2–5.5	
— .30 to — .21			4	4	2.4–2.5	4	4.8–5.1	3
— .20 to — .11		1	5	6	2.2–2.3	1	4.4–4.7	2
— .10 to — .1	1		5	5	2.0–2.1	10	4.0–4.3	1
.0 to + .9	1	1	5	7	1.8–1.9	10	3.6–3.9	3
+ .10 to + .19	1		4	6	1.6–1.7	7	3.2–3.5	9
+ .20 to + .29	2			3	1.4–1.5	17	2.8–3.1	12
+ .30 to + .39	5	2	4	6	1.2–1.3	16	2.4–2.7	6
+ .40 to + .49	4		9	10	1.0–1.1	23	2.0–2.3	11
+ .50 to + .59	4	1	6	6	.8– .9	11	1.6–1.9	17
+ .60 to + .69	7	4	8	9	.6– .7	21	1.2–1.5	33
+ .70 to + .79	5	7	17	17	.4– .5	28	.8–1.1	34
+ .80 to + .89	6	9	23	25	.2– .3	29	.4– .7	49
+ .90 to + 1.00	3	14	85	102	.0– .1	21	.0– .3	50

[1] Each of the averages being the average of the six resemblances of one pair of twins.

[2] My method of correcting the *r*'s by the differences is in general to alter no *r* that is above 60, but with values of *r* between — 100 and + 60, to add 5 (1.0 — difference) to the *r* and also 5 (.5 — difference). Rarely I also altered the correction somewhat, in view of the amount of the deviation.

ing that all the variable errors have combined to mask such a truly existent separation.

Take any group of these twins that you please as identical twins and you will find the group's chosen grading off imperceptibly into the remainder, or still worse, will find one of its pairs sharply different in sex, eye color, hair color, countenance, cephalic index or the like. The more carefully any one will examine Tables 13 and 14, the more impossible will seem the existence among twins of two groups, one of twins 'invariably of the same sex and exact or approximately exact physical equivalents of one another'; the other of twins 'either of the same or opposite sex and bearing no closer physical resemblance than is usual in children of the same family.'

The form of distribution of twin resemblance is apparently of

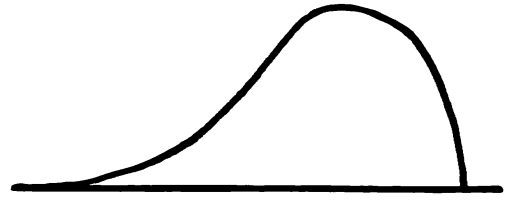


FIG. 8.

the somewhat common type Fig. 8 where a trait is very variable but has its mode close to an absolute limit of some sort. The distribution of the number of children in New England families is something like it: the mode being at two, and the upper limit being at eight, or ten or more.

This same general type of distribution is shown by the resemblances in each particular trait as well as by the general tendency to resemblance. Table 15 presents the facts, the r's being used as the measures of individual resemblance. It must be remembered that, as was pointed out on pages 46–48, these resemblances must be considered in the light of their derivation; and any careless interpretation, such, for instance, as saying that the greatest resemblance found in ninety-nine times that found in some twins, must be avoided. With all discretion in interpretation, however, one may be sure of (1) the general existence of close resemblance as the *most frequent* fact, (2) an extreme variability toward low resemblance, or even greater unlikeness than exists between two unrelated individuals of the same sex and age and (3) the absence of any sharp break into two species of resemblance.

The *more frequent* occurrence of very close resemblance in a *single trait than in* the average of several traits witnesses to the *specialization of inheritance*, to the fact that the great similarity of

TABLE 15

Resemblances of single pairs in single traits.

	Height	Height Sitting	Height Sitting/Ht.	Circumference of Head	Width of Head	Cephalic Index	Perception Combination	Association Combination	Median of Seven Coefficients from inexact Measures
— 1.00 — .91	2	1	3	3	2	1	6	2	
— .90 — .81	1	1				2	2		
— .80	1	1				2	1	1	
— .70							1	1	
— .60				1			1	1	
— .50	1			1			1	1	1
— .40					1		1	1	
— .30	1	1	1		1	1	1		1
— .20	1	1	2		1	1	1		1
— .10	1	1	2	1	1				1
.0	2		2	2	2			1	1
+ .10	2	2	1			2		1	1
+ .20	1		1	1			1	1	3
+ .30	3	2		2	1		2	2	1
+ .40	2	1	2	1	1	4	2		3
+ .50	2	1	1		2	1	5	2	
+ .60	1	1	1	2	2	2	1	2	5
+ .70	3	6	1	4		2	1	6	6
+ .80	6	1	5	7	8	3	5	4	9
+ .90 + 100	20	19	17	14	17	18	16	15	4
No. of pairs	50	39	39	39	39	39	48	41	37

a pair in some one trait rarely is accompanied by equal similarity in all.

§ 19. *The Views of Other Investigators*

So far as I know, Francis Galton and H. H. Wilder have been the only investigators of the resemblances of twins who have gathered data capable of being used as evidence concerning the form of distribution of resemblance in twins. Galton took finger-prints of seventeen pairs of twins. In his report of the results[1] he does not draw any conclusions or make any suggestions about the existence of two species of twins, though in his 'History of Twins'[2] he accepts such species as a fact. The finger prints of the 17 pairs of twins show rather a continuous gradation from close to little resemblance. The patterns on three fingers being recorded and agreement in pattern being scored =, partial agreement ·· and disagreement ×, we have:

[1] *Finger Prints*, p. 186 ff.

[2] *Inquiries into Human Faculty*, pp. 216–243. This paper of Galton's is more easily obtained in a reprint in the *Teachers College Record*, May, 1901.

= = = in 2 pairs
= = · in 1 pair
= = , in 2 pairs
= · · in 1 pair
= · , in 3 pairs
= , , in 1 pair
· · , in 1 pair
· , , in 4 pairs
, , , in 1 pair

These facts are, so far as they go, evidence against the existence of two well-defined species of resemblance.

Wilder[1] is convinced of the separation of twins by degrees of resemblance into 'duplicate' and 'fraternal,' as is shown by the quotation in § 16. His paper is in part an attempt to demonstrate that palm- and finger-prints furnish a sure diagnosis of the species to which any pair belongs. But to do this he has to assert that out of twelve pairs of twins, two, who were first thought to be identical in countenance and the like, and so classed as duplicate twins, were really not so: and to leave a third pair which, to all appearances save in the prints, were identical, but whose prints were decidedly unlike, either as a contradiction of his theory, or as a 'fraternal' pair as closely alike in physical traits other than the prints as are his 'duplicate' pairs. Moreover, the pairs which he unreservedly accepts as 'duplicates' are not exactly alike in the prints.

Thus his facts are really much better in accord with the distribution of resemblance in a uni-modal form with its mode at close resemblance and varying to a low limit, than with the distribution into two sharp species.

Before passing to the next topic in order, it may be well to note a possible objection to the argument of this section. It may be said that by original nature the pairs of twins here studied were divided sharply into two species, but that environmental forces have filled up the gap by making enough of the duplicate twins grow unlike and enough of the fraternal twins grow alike. Apart from the general artificiality and improbability of this speculation, it is flatly denied by facts in the case of the cephalic index. Moreover, if any one will select which individuals have been thus displaced from their natural position in the scale of resemblances, and then seek to explain the displacements in accordance with any known facts, he will soon abandon the hypothesis.

[1] *American Journal of Anatomy*, Vol. III., No. 4.

§ 20. *The Mode of Genesis of Twins*

If the form of distribution described in the last section is the true one, the probable nature of the causes determining the similarity of twins should be such as to produce a very great variability, with, as a central tendency, a resemblance denoted by a coefficient of correlation of about .75. If twins develop always from two ova, there must be some cause for the far greater similarity of the individuals growing from, and presumably of the initial structures of these ova, than of two non-twin ova. If twins develop always from one ovum after fertilization, there must be some cause for the great variability in resemblance. If, in spite of discarding the doctrine of two species of resemblance, we retain that of two species of origin, and regard twins as arising in two ways (*a*) from one fertilized ovum, and (*b*) from two, the last difficulty remains; for among any group of twins chosen as representative of the former sort of genesis, there will be a wide variability in resemblance in some traits.

It seems to the author that the facts allow us to explain the resemblance in the first case more easily than the variability in the second and third cases. If the variability among germs produced at the same time were much reduced below that of germs produced years apart, and likewise for the ova, there would be a proportional increase in the resemblances of children born at the same time over ordinary siblings. The combined action of the variability of the germs and the ova could perfectly well give the general tendency to resemblance and its variability, as we find them in twins. The specialization of resemblance in twins would also be naturally accounted for by whatever causes account for the specialization of resemblance in siblings generally.

The objections to the genesis of any considerable percentage of twins by the development of two individuals from one ovum after fertilization are: first, this specialization, which is well-nigh universal; second, the non-appearance of any such well-defined group of especially similar twins; third, the fact of triplets all three as identical as any two twins; and fourth, the too great frequency of close resemblance. The first two points have been sufficiently emphasized.

The third has, oddly enough, not been used as an argument, but surely the splitting of a fertilized human ovum into three identical divisions is incredible; and a separation at any stage into fourths all perfectly alike except in the one unlikeness which makes one of the four promptly cease to develop, seems to require the interference of a *deus ex machinâ*. And if triplets, all as much alike as any twins are, do probably demand at least two ova, why should we not have two ova for even the most similar twins?

As to the fourth point, it would seem improbable that the splitting of a fertilized ovum with survival of both resulting embryos should in the human species occur anywhere nearly as frequently as the contemporaneous development of two ova. Yet the proportion of pairs showing indistinguishable eye color and such likeness of countenance as would confuse an ordinary observer is over 20 per cent.; the number of pairs (using 6–9 year olds) of different sex is only 26 per cent., and the least difficult place to make a division into two species would, in the case of Galton's returns[1] as well as my own, leave us with at least 50 per cent. of 'more alike' twins.

The objections to the genesis of *all* twins by the splitting of one fertilized ovum are the first and third of the four noted in the preceding, and also the wide variability in the general tendency to resemblance.

The careful reader will have observed that in all that I have said there is no implication of the impossibility of the birth of two or more monsters, or of twins, from a single fertilized ovum. The argument would deny, not the possibility of such an event, but that it was the mode of genesis of any considerable proportion of twins, no matter how similar.

[1] Galton writes that he received 80 cases of close similarity, 35 of which gave exact information. 20 cases of less likeness were reported exactly.

CHAPTER IV

The Specialization of Resemblance

§ 21. *The Means of Measuring the Specialization of Resemblance*

By the specialization of resemblance I refer to the failure of likeness in one trait to imply an equal likeness in other traits, *e. g.*, to the fact that a pair of twins indistinguishable in eye color or stature may differ notably in cephalic index or efficiency in perception, etc.

To measure the extent of such specialization, exact measures of individual resemblance are needed. The difficulties of obtaining these, particularly in mental traits, have been explained in §§ 17–18. Given such measures, the specialization of resemblance would be measured directly by the variability of the resemblances in different traits of the same twin pair or inversely by the coefficient of correlation between resemblance in one trait and resemblance in another. I shall not attempt such formal and precise measurements of specialization, but shall demonstrate the fact and show roughly the degree of specialization less formally and without exact numerical estimates of its general tendency. I shall, for instance, ask how far identity (by which I mean indistinguishableness) in hair and eye color may coexist with obvious differences in stature and cephalic index. All the data which I shall use are to be found in the tables of deviation measures and of approximate measures of individual resemblances (Tables 6, 10 and 13).

§ 22. *The Data on the Specialization of Resemblance*

The general tendency to resemblance as shown by the median of the resemblances in height, height sitting, circumference of head, cephalic index, ratio of height sitting to total height, perception combination and association combination, is by no means commensurate with the resemblance in eye and hair color. Twins who differ in both eye and hair color *may* resemble each other far more closely than do some of those indistinguishable in eye color, and indistinguishable, or much alike, in hair color. The facts are given in Tables 16 and 17.

TABLE 16

The medians of the resemblances in height, height sitting, circumference of head, cephalic index, ratio of height sitting to total height, perception and association,—of twins, (1) alike in both eye and hair color, (2) alike in either eye color or hair color and (3) alike in neither hair nor eye color.

Of twins alike in both	Of twins alike in one	Of twins alike in neither
97	95	93
97	95	85
97	87	81
96	80	73
96	78	58
95	77	34
95	70	22
94	63	0
92	51	—60
85	42	
80	3	
76		
69		
59		
57		
41		

TABLE 17

The averages of the resemblances in the six physical traits of Table 16 of the groups of twins there mentioned.

Of twins alike in both	Of twins alike in one	Of twins alike in neither
94	96	89
91	84	86
87	81	63
85	77	56
75	61	43
74	56	38
71	55	32
71	46	1
67	42	—10
67	37	
66	17	
64		
58		
49		
39		
36		
29		
28		

Resemblance in eye and hair color is only loosely correlated with resemblance in mental traits. Twins much alike in the former may be little alike in the latter, and *vice versa*. The facts are given in Table 18.

TABLE 18

The average of the two most accurately determined resemblances in mental traits (perception combination and association combination) of twins alike in both eye and hair color, alike in one and alike in neither.

Using pairs where one member is remote from central tendency.

Of those alike in both		Of those alike in one		Of those alike in neither	
Perception	Association	Perception	Association	Perception	Association
100	97	100	100	100	87
100	97	100	99	94	72
98	95	83	99	93	70
97	94	81	94	58	27
92	94	?(high)	86	34	10
92	82	67	7	— 40	— 73
84	79	48	4	— 57	
54	72	28		— 88	
51	59	— 70		— 99	
27	53				
— 53	— 44				
— 95					
— 97					
Medians 84	82	75(?)	94	34	49

Using pairs where both members are near to the central tendency.

Of those alike in both		Of those alike in one		Of those alike in neither	
Perception	Association	Perception	Association	Perception	Association
98	100	82	— 65	— 100	38
90	71	— 86	— 100		— 60
— 14					— 100
— 98					

Resemblance in general appearance and countenance is correlated by no means perfectly with resemblance in other traits. The facts are given in Table 19.

TABLE 19

The medians (1) of the resemblances in three head measurements, (2) of the resemblances in three stature and arm measurements, (3) the resemblances in perception, and (4) the resemblances in association,—of twins of the same sex, closely alike, and not much alike in countenance.

Head Measurements		Stature Measurements		Perception		Association	
Of those alike in appearance and countenance	Of those unlike	Of those alike	Of those unlike	Of those alike	Of those unlike	Of those alike	Of those unlike
99	100	99	93	100	100	100	94
98	97	98	86	100	100	100	82
97	96	96	80	98	93	99	79
97	90	95	76	98	92	97	72
96	80	95	71	97	67	97	70
95	59	92	46	95	58	95	4
95	44	92	34	92	48	94	— 60
92	41	91	29	90	34	72	— 73
85	32	86	— 9	84	— 98	71	— 100
84	0	80	— 11	83	— 99	65	
83		73		82		59	
80		73		54		53	
78		71		51		— 44	
60		67		28			
43		57		22			
28		45		— 14			
— 71		35		— 97			
Medians 85	70	86	59	84	63	94	70

Resemblance in perception is by no means perfectly correlated with resemblance in association. The facts are given in Table 20.

TABLE 20

The correlation of resemblance in the combination of 1, 2 and 3 with the resemblance in the combination of 4, 5 and 6. Each pair of numbers gives the two r's for a pair of twins.

Using those pairs one member of which is not near the central tendency.

Perception	Association	Perception	Association	Perception	Association
100	95	84	97	—40	27
100	95	83	99	—57	87
100	94	74	96	—73	94
100	94	58	72	—97	59
100	86	54	—44		
100	86	53	—33		
100	—73	48	4		
98	97	33	69		
97	65	28	100		
94	10				
93	70				
92	82				

Using those pairs one member of which is in one or both traits near the central tendency.

97	100	84	75	— 14	53
90	72	81	— 65	— 58	96
		67	—100	— 86	99
		51	71	— 88	—100
				— 95	100
				— 98	79
				— 98	— 60
				— 99	38
				—100	

Resemblance in stature and arm measurements is by no means perfectly correlated with resemblance in head measurements. The facts are given in Table 21.

TABLE 21

Body.—Median of resemblances in height, height sitting, ratio of height sitting to total height, length of forearm, ratio of length of forearm to body height.

Head.—Median of resemblances in width of head, circumference of head and cephalic index.

Each pair of numbers gives the two r's for a pair of twins.

Body	Head	Body	Head	Body	Head
100	—16	93	80	85	47
99	—71	93	80	82	77
99	—99	92	84	80	97
98	85	92	43	80	95
96	97	91	95	76	44
96	94	90	—16	73	99
95	83	86	32	73	60
95	78	86	28	71	99

Body	Head	Body	Head	Body	Head
71	41	45	95	— *1*	0
67	96	45	80	— *9*	100
61	97	35	97		
57	99	34	59		
57	92	29	96		
46	90	14	84		

The large amount of specialization of resemblance shown by the foregoing tables is probably in part due to the unreliability of the original measurements, to the unreliability of the measures of central tendency[1] and to the possibility of a low coefficient for a single pair who may be really closely alike but are both near the central tendency. It can not be entirely due to these causes; for in tracing back some of the instances of lack of correlation in resemblance, I find them to be unexplainable by any other influences than a real specialization of resemblance. Such is obviously the case in twins who are indistinguishable in eye color, but markedly unlike in hair color.

A just idea of the results which would appear in tracing back all these cases of lack of correlation of resemblances may be obtained from the thirteen pairs of twins who were alike in eye color, hair color and sex, and most closely alike in general appearance, especially of countenance (see Table 22).

From the individual coefficients, supplemented by the deviation measures, the difference between them in the case of each pair, and the median deviations of all twins in each trait, the reader can satisfy himself of the reality of the specialization shown. For in these cases there are frequent lacks of resemblance which can in no wise be due to anything in the process of measurement or calculation. Very many more such cases will be found by one who will take the trouble to examine Table 14 with care.

If we call indistinguishable eye color a resemblance of 100; similar hair color, a resemblance of 90–100; very much alike in countenance (this means that only those most familiar with the twins could tell them apart), 100; and alike (this means that for a stranger it would be impossible, or nearly so, to tell the twins apart), 95; and 'not exactly,' 90—the facts are as given in Table 22.

[1] It must be remembered that while this influence makes a lack of correlation in resemblance in some cases, it also makes an excess of it in others.

TABLE 22

Pair	Sex	Hair Color	Eye Color	Appearance	Height Dev. 80 Dif. 56			Height Sitting Dev. 22 Dif. 12.5			Circumference of Head Dev. 10 Dif. 7			Cephalic Index Dev. 25 Dif. 12			Height Sitting Dev. 16 Dif. 8			Combination of 1, 2, and 3 of Mental Tests Dev. 425 Dif. 896			Combination of 4, 5, and 6 of Mental Tests Dev. 260 Dif. 190		
					r	Deviations	Difference	r	Deviations	Difference	r	Deviations	Difference	r	Deviations	Difference	r	Deviations	Difference	r	Deviations	Difference	r	Deviations	Difference
5	All alike	All 90-100	All 100	95	57	—103 — 32	71	64	—25 — 9	16	99	+24 +23	4			5				98	+ 261 + 306	45			
8				95										99	+40 +46	6				—95	— 410 — + 301	711	99	+ 68 + + 83	15
11				90	—9	+ 65 — 8	68	71	—10 —24	14				99	—68 —75	7	100	+25 +26	1						
23				95	100	+ 62 + + 62	0	99	+ 7 + + 8	1				23	—71	25.5									
24				95	78	+156 + + 68	88							24	99	6	0	0 —27	27						
26				95	100	+867 +865	12				88	+29 +49	20	26						100	+2034 +1921	113			
27				95										27			71	—15.5 —37.5	22.5	100	+1493 +1452	41			
30				100	100	+ 44 + + 44	0	76	—11 —24	13				30											
32				95							99	—17 —19	2	82									53	+186 +642	456
35				90				100	—106 —109	8				35	—24	37							—44	+227 — 53	280
43				90										43			100	+10 +10	0	—97	+ 405 — 317	722			
47				95										47	97	4		+18.5 +14.5		51	+ 980 + + 269	711			
50				95				— 7	+ 1 —27	28				50	100	2	45	+ 7.5 +81	23.5						

EXPLANATION OF TABLE 22

This table gives facts which demonstrate the specialization of resemblance, by showing the existence of great and little resemblance in the same pair. The numbers beside the Dev.'s and Dif.'s at the top of the table give the median deviation of the whole group of 100 cases from the central tendency in the trait in question and the median difference between twin and twin of the same pair in the trait in question. The entries in the table give for each pair in each trait chosen the r for that pair, the deviations from the central tendency of the two numbers of the pair and the difference between them. If then a pair has a low r and a large difference or a low r and one large deviation, the r is surely significant of a really small resemblance. If a pair has a high r and a small difference relative to the deviations, the r is surely significant of a really great resemblance. Thus we may read off the facts concerning pair No. 5 as follows. Alike in sex, closely alike in hair color, very closely alike in eye color, very much alike in general appearance (nearly or quite indistinguishable), much less alike than twins in general in height, much less alike than twins in general in height sitting, very much more alike than twins in general in head circumference and in the combination of perception tests; or more briefly, alike in sex, 90–100, 100, 95, 97, 64, 99 and 98. In these 13 pairs,—those most alike of all the 39 in hair color, eye color and appearance,—we find in every case resemblances surely below 90, six cases of less resemblance than would be found in children of the same age taken at random, and fifteen cases of decidedly less resemblance than the average of twin resemblance. At the same time we find in other traits as great a resemblance as that in eye color and appearance.

§ 23. *The Interpretation of the Facts*

The facts presented in section 22 prove that the general tendency to resemblance of any two individuals can not be easily and surely estimated from a few traits. Obviously, we can not predict from the amount of resemblance in any one trait, the amount of others, except within limits, or as to a certain degree probable.

They are also strong evidence that heredity is itself highly specialized. It is perhaps possible that the variations in resemblance are due to environmental forces, that heredity works simply by giving a certain degree of all-around likeness. However, it strains all one's biological conceptions to endow environmental forces with the ability to alter original tendencies in eye color or cephalic index, or to suppose that two twin children meet, before the ages of nine to fourteen years, with environments different enough to make original close similarities in perception, association or ratio of height sitting to total height, change into comparative unlikeness. The only objection which can rightly be made against the hypothesis that the specialization of resemblance is due to the specialization of inheritance is that it demands so much complexity and specialization of the germs. But this is, after all, a question of fact. The germs are surely complex enough to parallel the structural traits of a species, including the anatomical and physiological basis of its re-

flexes and instincts. They may be, in addition, complex enough to parallel the traits of an individual.

It seems advisable, therefore, to choose, for the present, the hypotheses (1) that original nature is highly specialized, (2) that the causes determining the original nature of one member of a twin pair are largely, but by no means altogether, identical with those determining the original nature of the other member and (3) that the causes producing likeness in one trait are far from being identical with, or inevitably accompanying, those producing likeness in other traits.

Evidence of the first hypothesis has been found, I believe, by every student of heredity who has used quantitative methods and been conscious of the problem itself. The second and third hypotheses, which support and make more definite the first, rest in the case of twins upon only the data of this section. It is hardly necessary to call attention to the fact that if in a group of pairs chosen from those most closely alike on the whole, such specialization of heredity occurs, it will *à fortiori* occur in less similar twin pairs and in ordinary siblings.

CONCLUSION

§ 24. *Summary of Results*

THIS investigation proves the existence of close similarity of twins in physical and mental traits and gives approximate measures of the resemblances in eight physical and six mental traits. It shows that such likenesses and differences in environment as act upon children living in New York City and attending its public schools are utterly inadequate to explain the likenesses and differences found in the traits measured, and are in all probability inadequate to explain more than a small fraction of them.

The arguments concerned the lack of differences in the amount of resemblance (1) between young and old twins, (2) between traits little and traits much subject to training and (3) between mental and physical traits, and also the great increase in resemblance of twins over ordinary siblings.

The resemblance of twins was found to be approximately .80 or .75 to .80 in amount.

The form of distribution of twin resemblance seems to be that of a fact with a central tendency at about .80 and with a great variability, restricted towards the upper end by the physiological limit of complete identity. Such a distribution would be most easily explained by the genesis of twins as a rule from two ova and by a great reduction of the variability of contemporaneous germs and ova below that of germs and ova developed at different times.

The resemblance of any pair is far from uniform as we pass from trait to trait. An almost necessary inference is that heredity is itself highly specialized, each minute feature of physical and mental make-up possessing its representative in the germs *and varying more or less independently of other features of the same germ.*

Special care has been taken to so arrange the material that any investigator may readily combine the measures of this research with data obtained by himself or use them for studies of individual differences, correlation and the like; and that any critic may repeat the calculation of resemblances after any plan that he approves. Nothing need be accepted upon my authority except the original gross measures and the details of the estimation of central tendencies from

which to calculate deviation measures. The original measures are given for each individual in Tables 5 and 8; the deviation measures which are the basis of all correlations and later arguments are similarly given in full in Tables 6 and 10. The derivations of central tendencies and variabilities would have been printed in full, except for the expense and the very slight gain to the critic.

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